SMARTFAMILY2.0: A refined mobile health intervention to promote physical activity and healthy eating in a family setting – A randomized-controlled trial

Janis Fiedler, Kathrin Wunsch, Sebastian Hubenschmid, Harald Reiterer, Britta Renner, Alexander Woll

Submitted to: JMIR mHealth and uHealth
on: August 19, 2024

Table of Contents

SMARTFAMILY2.0: A refined mobile health intervention to promote physical activity and healthy eating in a family setting – A randomized-controlled trial

Janis Fiedler[1*] PhD; Kathrin Wunsch[1*] PhD; Sebastian Hubenschmid[2]; Harald Reiterer[2] PhD; Britta Renner[3] PhD; Alexander Woll[1] PhD

[1]Institute of Sports and Sports Science Karlsruhe Institute of Technology Karlsruhe DE
[2]Department of Computer and Information Science University of Konstanz Konstanz DE
[3]Department of Psychology University of Konstanz Konstanz DE
[*]these authors contributed equally

Corresponding Author:
Kathrin Wunsch PhD
Institute of Sports and Sports Science
Karlsruhe Institute of Technology
Engler-Bunte-Ring 15
Karlsruhe
DE

Abstract

Background: Many mobile health (mHealth) apps focus on promoting physical activity (PA) and healthy eating (HE). However, there is limited empirical evidence regarding their effectiveness in initiating and sustaining behavior change, particularly among children and adolescents. Considering that behavior is influenced by social contexts, it is essential to take core settings like family dynamics into account when designing mHealth apps.

Objective: The purpose of this study was to further develop and refine the SMARTFAMILY app targeting PA and HE in a collective family-based setting by enhancing design and usability, as well as by adding gamification aspects, health literacy, and just-in-time adaptive interventions (JITAI) to the first version of the app.

Methods: The SMARTFAMILY2.0 app, based on behavior change theories and techniques, was developed, implemented, and evaluated. The app was used in a collective family setting, with family members using it individually and cooperatively. In a cluster-randomized controlled trial, the intervention group (IG) used the app for three consecutive weeks, while the control group (CG) received no treatment. Primary outcomes included physical activity (PA) measured through self-reports and accelerometry, as well as self-reported fruit and vegetable intake (FVI) for health eating (HE). Secondary outcomes included intrinsic motivation, behavior-specific self-efficacy, and the Family Health Climate (FHC). A follow-up assessment (T2) was conducted four weeks after the post-measurement (T1) to assess intervention effects. Multilevel analyses were performed in R, considering the hierarchical structure of individuals (level 1) within families (level 2).

Results: Overall, 55 families (28 CG, n = 105; 27 IG, n = 104 participants) were recruited for the study. Three families (3 KG, n = 12) chose to drop out of the study due to personal reasons before T0. Overall, no evidence for meaningful and statistically significant increases in PA was observed in favour of the IG our physically active sample. However, the app elucidated positive effects in favor of the intervention group for FVI diary (T0-T1; p = .031), joint PA (T0-T1 and T0-T2; p <.026), and joint family meals (T0-T1; p =.004).

Conclusions: The SMARTFAMILY2.0 trial evaluated a mHealth intervention designed to promote PA and HE within families. Despite incorporating a theoretical foundation, several behavior change techniques based on family life and gamification and JITAI features, the intervention did not significantly increase PA levels among physically active participants. FVI intake, joint PA, and joint meals were improved within the intervention group. Previous studies on digital health interventions have produced mixed results, and family-based mHealth interventions remain rare, with limited focus on whole-family behavior and randomized controlled trials. To enhance intervention effectiveness, future app development could consider incorporating even more advanced features and should focus on inactive participants. Further research is needed to better understand intervention engagement and tailor mHealth approaches for primary prevention efforts. Clinical Trial: The study is registered with the

German Clinical Trials Register under the registration number DRKS00010415.

(JMIR Preprints 19/08/2024:65558)
DOI: https://doi.org/10.2196/preprints.65558

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✔ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.

Only make the preprint title and abstract visible.

No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Original Research

SMART*FAMILY*2.0: A refined mobile health intervention to promote physical activity and healthy eating in a family setting – A randomized-controlled trial

Janis Fiedler*[1], PhD; Kathrin Wunsch*[1], PhD; Sebastian Hubenschmid[2], MSc; Harald Reiterer[2], PhD; Britta Renner[3], PhD; & Alexander Woll[1], PhD

*Authors contributed equally

[1] Institute of Sports and Sports Science, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany
[2] Department of Computer and Information Science, University of Konstanz, 78457 Konstanz, Germany
[3] Department of Psychology, University of Konstanz, 78457 Konstanz, Germany

Article type: Original Research

Running title: SMART*FAMILY*2.0*:* family-based mHealth intervention for physical activity and healthy eating

Number of words in abstract: 455
Number of words in text: 5799
Number of Figures: 4
Number of Tables: 2

Corresponding author:

Kathrin Wunsch
Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Engler-Bunte-Ring 15, 76131 Karlsruhe, Germany.

Email: Kathrin.wunsch@kit.edu
Phone: 0049 721 608 45431
Fax: 0049 721 608 44841

Trial registration

The study is registered with the German Clinical Trials Register under the registration number DRKS00010415.

Conflicts of interest

All authors declare they do not have any conflicts of interest. Authors/evaluators are distinct from the developers/sponsors of the intervention.

Funding

This research was supported by the Federal Ministry of Education and Research within the project SMARTACT. BMBF Grant: FKZ 01EL1820C. We also acknowledge support by the KIT-Publication Fund of the Karlsruhe Institute of Technology.

Acknowledgements

The authors thank Dr. Jens-Peter Gnam, Laura Berkhan, Jelena Bezold, Dr. Christina

Niermann, Dr. Tobias Eckert, Nicolas Mahler, Fabian Fernandez-Pachecho, and Adam Kaczmarcyk for their support within the trial as well as all partners involved in the research association SMARTACT.

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

Abstract

Background: Many mobile health (mHealth) apps focus on promoting physical activity (PA) and healthy eating (HE). However, there is limited empirical evidence regarding their effectiveness in initiating and sustaining behavior change, particularly among children and adolescents. Considering that behavior is influenced by social contexts, it is essential to take core settings like family dynamics into account when designing mHealth apps.

Objectives: The purpose of this study was to further develop and refine the SMARTFAMILY app targeting PA and HE in a collective family-based setting by enhancing design and usability, as well as by adding gamification aspects, health literacy, and just-in-time adaptive interventions (JITAI) to the first version of the app.

Methods: The SMART*FAMILY*2.0 app, based on behavior change theories and techniques, was developed, implemented, and evaluated. The app was used in a collective family setting, with family members using it individually and cooperatively. In a cluster-randomized controlled trial, the intervention group (IG) used the app for three consecutive weeks, while the control group (CG) received no treatment. Primary outcomes included physical activity (PA) measured through self-reports and accelerometry, as well as self-reported fruit and vegetable intake (FVI) for health eating (HE). Secondary outcomes included intrinsic motivation, behavior-specific self-efficacy, and the Family Health Climate (FHC). A follow-up assessment (T_2) was conducted four weeks after the post-measurement (T_1) to assess intervention effects. Multilevel analyses were performed in R, considering the hierarchical structure of individuals (level 1) within families (level 2).

Results: Overall, 55 families (28 CG, n = 105; 27 IG, n = 104 participants) were recruited for the study. Three families (3 KG, n = 12) chose to drop out of the study due to personal reasons before T_0. Overall, no evidence for meaningful and statistically significant increases in PA was observed in favour of the IG our physically active sample. However, the app elucidated positive effects in favor of the intervention group for FVI diary (T_0-T_1; p = .031), joint PA (T_0-T_1 and T_0-T_2; p <.026), and joint family meals (T_0-T_1; p =.004).

Conclusion: The SMART*FAMILY*2.0 trial evaluated a mHealth intervention designed to promote PA and HE within families. Despite incorporating a theoretical foundation, several behavior change techniques based on family life and gamification and JITAI features, the intervention did not significantly increase PA levels among physically active participants. FVI intake, joint PA, and joint meals were improved within the intervention group. Previous studies on digital health interventions have produced mixed results, and family-based mHealth interventions remain rare, with limited focus on whole-family behavior and randomized controlled trials. To enhance intervention effectiveness, future app development could consider incorporating even more advanced features and should focus on inactive participants. Further research is needed to better understand intervention engagement and tailor mHealth approaches for primary prevention efforts.

Keywords: mobile application; telemedicine; behavior change; health behavior; family; primary prevention; exercise; diet, food and nutrition; randomized controlled trial; accelerometer; wearable electronic devices; social-cognitive determinants; just-in-time adaptive intervention; digital intervention

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

Abbreviations: PA: physical activity, HE: healthy eating, IG: intervention group, CG: control group, SF: SMART*FAMILY*, FHC: Family Health Climate, FVI: fruit and vegetable intake; EMA: ecological momentary assessment; JITAI: just-in-time adaptive intervention; mHealth: mobile Health, app: application; BLE: Bluetooth Low Energy, BCT: behavior change technique

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

Introduction

Background

The health benefits of sufficient physical activity (PA), reduced sedentary behavior (SB) including screen time, and healthy eating (HE) are manifold [1–4] and include benefits regarding all-cause mortality, cardiovascular function, cancer, and metabolic and mental health among others [3,5–7]. Hence, engaging in different health behaviors should be emphasized from young ages onwards. Guideline adherence is only high for PA in preschool children [8], but the older the children get, it becomes less likely that they sufficiently engage in PA [9–11]. Adherence to screen time guidelines is generally low [12,13], and children are known to make frequently unhealthy food choices [14–17]. It has been observed that the majority of children and adolescents (81%) and a significant proportion of adults (23%) do not meet the recommended levels of PA and HE, specifically in terms of fruit and vegetable intake (FVI), globally [18]. Research has shown that there is a dose-response relationship, meaning that even small increases in PA and/or HE can have positive effects on the physiological and psychological health of children and adolescents [19] and adults [2,20–23].

A promising way to achieve sustainable behavior change is to create interventions that target children and adolescents, as longitudinal studies showed that behavioral patterns in childhood and adolescence have a low-to-moderate influence on PA patterns in adulthood [24–29]. As children and adolescents are strongly dedicated to siblings and parents, social contexts like the family context need to be involved in intervention development, as health behaviors are affected by social relations and ties [30,31]. By implementing the family context into the intervention design, HE [32] and PA [33,34] can be facilitated more sustainably by targeting variables of daily family life like common meals [35–37]. Results of intervention studies also indicate that social support is significantly associated with the continuation of exercise programs [38–42] as well as participation in weight-loss interventions [43–45]. Therefore, both parents and their children can benefit from a behavior change intervention at the family level.

To deliver such interventions and individualize them to the different needs of participants, mobile health (mHealth) technologies are upcoming developments [46]. Smartphone-based applications (apps) in particular are promising to change health behavior and be cost-effective on a large scale [47–49]. Recent reviews and meta-analysises provide preliminary evidence for the effectiveness of app-based health behavior change [50–52]. Here, certain facets are related to intervention effectiveness [53], including a theoretical foundation and behavior change techniques (BCTs, [54]) like goal setting, self-monitoring, social support [55,56], implementing the intervention in a social context [30,57] and the tailoring of interventions to participants needs [50,52,58]. These aspects were already included in the SMART*FAMILY*1.0 trial [59]. Based on current literature, this app was further developed by revising user interface and usability and by adding and consolidation several other features that have been shown to positively influence intervention effectiveness, like gamification [60], physical literacy [61,62], further BCTs [54], ecological momentary assessments (EMA) [63] and just-in-time adaptive interventions (JITAIs) [64]. Recent developments in technology, mobile sensing, and wireless communication enable researches to deliver JITAIs [64,65] at the most promising time for behavior change and adapt them in real time to sensor or participant input. The evidence for these interventions is preliminary but promising to maximize effectiveness while minimizing participant burden [59,66,67].

Overall, there is a lack of randomized-controlled mHealth studies targeting both, children and adults within a social system aiming at health behavior change of more than one behavior [68] that use important key facets of effective interventions like BCTs and a theoretical foundation and incorporate JITAIs [65,69,70].

Objective

The SMART*FAMILY*2.0 trial aimed at refining the existing mHealth intervention app [59] that incorporates the family as a social system. Here, additional BCTs, gamification features, physical literacy aspects and a JITAI were integrated and the functionality and design of the app was improved. As before, the behavior of children *and* parents was targeted within the SMART*FAMILY*2.0 app to induce family- and individual-based behavior changes. For more details and the complete study protocol see [71]. A positive influence of the refined mHealth intervention on PA variables steps and MVPA and the HE variable FVI in the whole family was hypothesized.

Methods

Study Design

The study was conducted and described according to the corresponding study protocol and the CONSORT-EHEALTH checklist [72]. A graphical representation of the SF2.0 trial is depicted in Figure 1. Outcome evaluations were conducted at three time points: baseline (T_0), immediately after the 3-week intervention (or absence of intervention) phase (post; T_1), and four weeks after the post-measurement (follow-up; T_2). Participants were cluster-randomized into one of two groups: an intervention (IG) or a waiting-control group (CG). Given that the study protocol is freely accessible, the study design and measurements will be described very briefly. For a comprehensive overview, please consult the study protocol [71].

--- please insert Figure 1 here ---

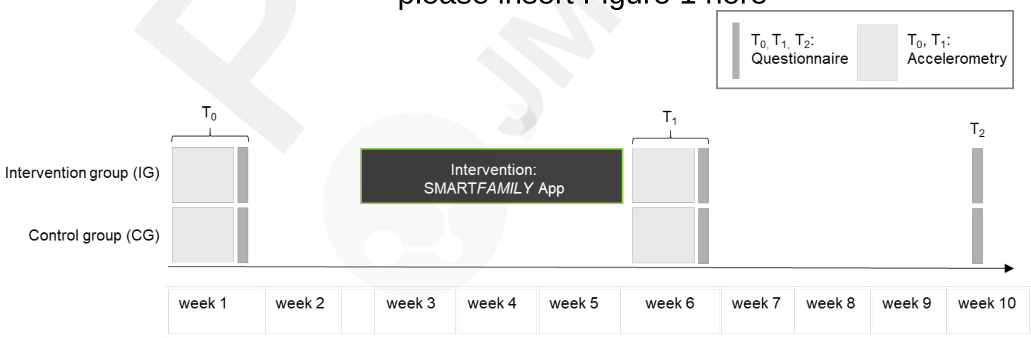


Figure 1. Detailed study design.

All eligible members of each family attended an initial visit to the research facility, during which they were provided with detailed instructions on how to utilize various tools that would be used throughout the study. These tools encompassed accelerometers, which recorded levels of PA, as well as paper diaries for monitoring behavior over time. This procedure was changed to online instructions and mailing of the material during the study due to Covid-19 restrictions. At the end of this initial phase, participants also responded to inquiries about their habits and behaviors

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

during the preceding week, serving as a baseline measurement. This information was subsequently shared with intervention participants to enable them to establish family goals based on this starting point.

Participants assigned to the intervention group were given specially designed smartphones embedded with our "SMART*FAMILY*2.0" app. The development of the app followed an iterative approach, incorporating feedback from the prior app, the target audience and domain experts. Insights from previous research conducted as part of the SMARTACT project and behavioral theories also informed the app's creation. The programming of the applications was undertaken by the Human-Computer Interaction Workgroup at the University of Konstanz, as a component of the SMARTACT project. To ensure equitable access to technology, study personnel provided all participants with study smartphones. Families were thoroughly briefed on the app's functionality, with a study manual distributed to aid their comprehension, and study staff were available to address any queries or concerns that arose. Moreover, the accelerometers worn by participants were wirelessly synchronized with the smartphones via Bluetooth low-energy connections.

During the onset of the three-week intervention, families in the intervention group were instructed to establish collective weekly goals related to PA and HE. These objectives encompassed achieving a specific step count, engaging in appropriate levels of moderate/vigorous PA, planning enjoyable family activities, sufficient FVI, and having joint family meals. Families were instructed to collaborate in formulating these goals based on their previous performance as assessed during the baseline evaluations. To facilitate this process, the goals for the entire family were set on a single smartphone, and the app sent notifications every Sunday to prompt the setting of new goals. During the initial explanation by study staff, participants were encouraged to strive for progressively more ambitious yet attainable goals based on their past behaviors. As part of the program, participants regularly reviewed and adjusted their goals to ensure they remained challenging yet manageable, fostering ongoing improvement. The app-based intervention also incorporated a just-in-time adaptive intervention [64,65], delivered by a coach, which prompted users to engage in physical activity after prolonged periods of inactivity. Inactivity was defined as one hour with less than 100 steps and less than 2 minutes with >2 metabolic equivalents (MET) during waking hours. Additionally, the coach provided daily progress updates towards the goals, motivational messages, up to 5 informational and entertaining facts per day, and ecological momentary assessments regarding sleep quality and core affect. Participants in the non-intervention control group did not receive any materials or communication during the intervention period. All smartphones were collected after the conclusion of the intervention period. Consequently, the intervention group did not have access to the app during the T_1 measurement or thereafter.

The app included 14 BCTs [54] for the intervention group and no BCT for the control group. Intervention BCTs were: behavioral goal-setting, prompt review of behavioral goals, prompt self-monitoring of behavior, provide feedback on performance, plan social support/social change, prompt identification as role model/position advocate, set graded tasks, shaping, prompt rewards contingent on effort or progress toward behavior, provide rewards contingent on successful behavior, barrier identification/problem solving, teach to use prompts/cues, and prompt review of behavioral goals.

After the intervention or control period ended, participants proceeded to undergo two additional testing sessions (T_1 and T_2). Throughout the entire process, strict adherence to ethical standards was maintained, and measures were implemented to safeguard personal data. The research study employed a single-blind design, whereby participants were unaware of their group assignment. Furthermore, prior to implementation, the survey instruments underwent thorough evaluation to ensure user-friendliness and technical reliability.

Eligibility Criteria and Ethical Approval

Households consisting of at least one adult caregiver and one child older than ten years of age living together were invited to participate. In cases where applicable, additional siblings - including younger siblings - were also welcome to join the project. All participants were required to possess basic proficiency in operating mobile devices, have the physical capability to engage in physical activity independently, and effectively communicate in German. Prior to the commencement of the study, all participants, including minors, parents, or legal guardians, provided informed written consent. The research study received full ethical approval from both the University of Konstanz and the Karlsruhe Institute of Technology. The study adhered to the guidelines outlined in the Helsinki Declaration.

Randomization and Blinding

This study employed a cluster-randomized controlled design to compare two distinct groups: an Intervention Group (IG) that received the intervention and a Control Group (CG) that did not receive any treatment. Families who provided consent were randomly assigned to either group using a straightforward allocation scheme suitable for cluster trials (following 58). While participants in the IG were aware of the mHealth aspects of the study, participants in the CG were informed about their contribution to an epidemiological examination of physical activity and overall health. To ensure accurate and reliable measurements, all participants wore accelerometers for one week twice over a ten-week duration. Additionally, participants completed various questionnaires during this period.

Participants

Participants were recruited in schools, school holiday programs, music schools, and sports clubs, via personal communication, newspapers, and email distribution lists of the Karlsruhe Institute of Technology. Overall, 55 families (28 KG, *n* = 105; 27 IG, *n* = 104 participants) were recruited for the study. Three families (3 KG, *n* = 12) chose to drop out of the study due to personal reasons before T_0.

Measurements

Physical activity measures

Device-based measured physical activity (accelerometry)

The study employed hip-worn 3-axial accelerometers (Move 3/Move 4, Movisens GmbH, Karlsruhe, Germany) placed on the right hip to continuously capture PA data. These accelerometers are recognized scientific research instruments, featuring a measurement range of ±16 g, an output rate of 64 Hz, physical dimensions measuring 62.3 mm x 38.6 mm x 11.5 mm, and weighing 25 g. Custom epoch lengths of 10 seconds were used to summarize the raw data recorded at 64 Hz. The choice of an epoch length of 10 seconds was based on the belief that shorter epoch lengths are more suitable for estimating vigorous PA and assessing PA in children due to their intermittent movement behavior [59,60]. The validity of a previous accelerometer version (Move 2), which utilizes similar digital signal processing techniques as the Move 3/Move 4 models, has been established and considered accurate for assessing steps [73] and energy estimation [74,75] in adults. Participants received instructions and demonstrations from a study instructor regarding the proper handling of the accelerometers. They were directed to wear the accelerometers throughout their waking hours and remove them only during activities such as showering, swimming, or certain sports involving bodily contact to minimize the risk of injuries. The outcomes measured using the accelerometer in this study were MVPA (>3.0 MET) and steps for all participants. MET values were calculated based on activity class determined by acceleration and barometric signals, which informed the estimation model. The model combined movement acceleration, altitude change, and demographic information to estimate MET values [75]. To be included in the analysis, accelerometer data needed to meet certain criteria. This included a minimum wear time of at least 8 hours per day for at least 4 of the 7 days during the measured week. Non-wear time was calculated in 30-second intervals using an algorithm that incorporated accelerometry and temperature signals over a 10-minute window. This algorithm distinguished between wear time, non-wear time, and sleep, as described elsewhere [64]. Valid measurements were determined by calculating the average of MVPA and steps per valid day and multiplying it by 7 to estimate the total minutes per week.

Self-reported physical activity

At the conclusion of each week of measurement, all participants were requested to complete the German version of the Global Physical Activity Questionnaire (GPAQ) [76]. This questionnaire asked participants to retrospectively report their activities during the previous week. To calculate the results for this study, we multiplied the reported number of days engaged in moderate physical activity (related to work, travel, and recreation) and vigorous physical activity (related to work and recreation) by the reported duration of each activity per day. We then added the values for moderate and vigorous physical activity to obtain the total minutes of MVPA per week. Additionally, a physical activity diary was utilized for all participants at time points T_0 and T_1. However, the results from the diary were not included in the current analysis due to non-comparability with other measures [77,78]. Both parents and children were instructed to independently complete their respective questionnaires and diaries.

Fruit and vegetable intake

The assessment of FVI involved two methods. Firstly, a single item in the questionnaire asked participants to report the total amount of fruits and vegetables consumed in the previous week [79]. Secondly, a detailed description of food consumption during time points T_0 and T_1 weeks was recorded in a diary. This included information such as the time of the meal, the ingredients, portions of FVI, and whether the meal was consumed within the family or alone.

Secondary Outcomes

Demographics

In the T_0 questionnaire, demographic information of the participants was collected, including sex, age, height, and weight.

Health status

Perceived general health was assessed using a single Item [79].

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

Intrinsic Motivation Toward Physical Activity

According to the Self-Determination Theory, the assessment of activity-related self-determination was conducted using the Behavioral Regulation in Exercise Questionnaire (BREQ-2) [80]. BREQ-2 assesses the manifestation of the five different regulation modes by the Self-Determination Theory, reflected by the subscales of amotivation (4 items), external (4 items), introjected (3 items), identified (4 items), and intrinsic (4 items) regulations. Responses were made on a 4-point Likert scale, ranging from (0) 'not true', (1) 'rather not true', (2) 'rather true' to (3) 'true'. For the purpose of analysis, a relative autonomy index (RAI) was constructed based on the subscales of the questionnaire. The RAI provides an assessment of the extent to which respondents perceive themselves as self-determined. To calculate the index, each subscale score was multiplied by its assigned weighting, and the weighted scores were then summed. A higher, positive RAI score indicates a higher level of relative autonomy, while a lower, negative score suggests a greater level of controlled regulation.

Intrinsic Motivation Toward Healthy Eating

The Regulation of Eating Behavior Scale [81] was used to assess dietary-related intrinsic motivation. The dimension "integated regulation" was omitted, resulting in a total of 5 subscales, coded from 0-3. A sum score was built analogous to the BREQ-2.

Intention

Intention towards PA and FVI as well as intention to use an app for PA and HE were assessed using single items [82].

Self-efficacy for Physical Activity and Healthy Eating

In order to assess activity-related self-efficacy and dietary-related self-efficacy, the study employed health-specific self-efficacy scales. These scales consisted of five items for each behavior-related dimension [83]. Participants were asked how certain they are to handle different health-specific barriers. Responses were given on a 4-point Likert scale, ranging from (1) very uncertain, (2) uncertain, (3) certain to (4) very certain. A sum score was built for both scales.

Family Health Climate

To assess shared perceptions and cognitions regarding health behaviors, the study utilized the Family Health Climate Scale (FHC) [84]. This scale consists of two separate scales: the FHC-PA scale and the FHC-nutrition (NU) scale. FHC-PA contains 14 items, which are assigned to the three subscales of value (5 items), cohesion (5 items), and information (4 items). FHC-NU includes 17 items, comprising the four subscales of value (4 items), cohesion (5 items), consensus (3 items,) and communication (5 items). Responses for each dimension were scored on a 4-point Likert Scale ranging from (0) 'not true', (1) 'rather not true', (2) 'rather true' to (3) 'true'. Sumscores were built for both scales.

Joint Physical Activity and Meals within the family

Joint PA and NU were assessed using a single item that inquired about the number of activities and meals in which the entire family participated during the previous week. The mean value per family was calculated and used for the analysis.

Statistical Analysis

The analyses were run with different packages of R [85] and RStudio [73]. The package 'ggplot2' was used for visualizations [86] following the instructions of Allan

and colleagues [87]. Mixed models were calculated using the package ‘lmerTest’ [88] with participants (level 1) nested in families (level 2) to acknowledge the hierarchical structure of the data. The result tables of the regression analyses were generated using the package ‘sjPlot’ [89]. Here, seven final models were calculated, one with each measurement method and outcome parameter (1 steps, 2 MVPA, 2 FVI intake per week, 1 joint PA, 1 joint NU) as dependent variables. Assumptions were checked using the visualization of the ‘performance’ package [90]. A hierarchical approach was used for the inclusion of the control variables and the model fit was assessed with the Akaike information criterion (AIC) for sensitivity analysis.
The predictor group (i.e. control = 0, intervention = 1) x time (dummy coded with T_0 as reference for T_1 and T_2) was included in the models to evaluate the interaction effect (main effect) of the intervention on the seven outcome parameters. To assess sensitivity regarding the additional variables, the secondary outcome parameters self-efficacy, intention, intention for app use, intrinsic motivation, and the family health climate were added either referring to PA or FVI depending on the outcome and the control variables health status, population (adult = 0, children = 1), sex (0 = male, 1 = female) and non-wear time per week - only for the device-based measured PA models - were tested for the inclusion in the random effect models. Additionally, the inclusion of random slopes and random intercepts were evaluated based on the model fit. The level of statistical significance was set a priori to $\alpha < .05$

Results

Data availability and participant characteristics

In total, 52 families (n=96 adults, 49/51% female/male, and n=101 children, 47/53% female/male) participated in the study. Technical issues with the application during the intervention, insufficient wear time of the accelerometer (i.e. less than 4 days with more than 8 hours wear time), and missing data for the self-reported items led to the inclusion of a different number of participants for each calculated model (depending on the outcome variables, see Appendix B/C). Participant characteristics of the 52 families separated by group (control vs. intervention), population (children vs. adults), and sex (male vs. female) are displayed in Table 1. Descriptive results for all included outcomes and predictors can be found in Table 2.

--- please insert Table 1 here ---

Table 1. Participant characteristics of the 52 families included in the SMART*FAMILY*2.0 trial. Displayed are the means and standard deviations (SD) of the parameters age and BMI divided by group (control or intervention), population (children and adults), and sex (male and female).

group	**control**				**intervention**			
population	**child**		**adult**		**child**		**adult**	
sex	male	female	male	female	male	female	male	female
m	25 (50%)	25 (50%)	23 (53%)	20 (47 %)	29 (57%)	22 (43%)	26 (49%)	27 (51%)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
age	11.5 (3.64)	10.4 (2.58)	45.1 (5.92)	46.4 (6.09)	11.4 (2.73)	12.1 (3.63)	45.0 (5.11)	46.7 (4.98)
BMI	18.9	17.9	24.3	27.2	17.2	18.5	23.5	27.1

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

	(3.68)	(3.19)	(3.86)	(4.51)	(3.12)	(2.82)	(3.66)	(3.66)

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

--- please insert Table 2 here ---

Table 2. Descriptive results of the 52 families included in the SMART*FAMILY*2.0 trial. Displayed are the means and standard deviations (SD) of the device-based measured parameters steps, moderate to vigorous physical activity (MVPA), and non-wear time (nwt) and the self-reported parameters moderate to vigorous physical activity measured by the global physical activity questionnaire (GPAQ MVPA), fruit and vegetable intake measured by a single item questionnaire (FVI quest) and by diary (FVI diary) and the secondary outcomes health status (health), intrinsic motivation towards nutrition (M intrinsic NU), intention to change physical activity and nutrition with an application (int app PA/NU) and physical activity (M intrinsic PA), intention towards changing physical activity (int PA), nutrition (int NU), and the family health climate (FHC NU and FHC PA), and self-efficacy for physical activity (self-efficacy PA) and healthy eating (self-efficacy NU) as well as joint physical activities (joint PA) and joint family meals (joint NU) divided by group (control or intervention), and population (children and adults). RAI = relative autonomy index.

Group	**Control**						**Intervention**			
	T0		**T1**		**T2**		**T0**		**T1**	
population	**child**	**adult**	**child**	**adult**	**child**	**adult**	**child**	**adult**	**child**	**adult**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Steps (counts/week)	57000 (26200)	55700 (17800)	64100 (23000)	54600 (17100)	–	–	64600 (25900)	54000 (14500)	61300 (24100)	49800 (20100)
MVPA (minutes/week)	579 (346)	621 (236)	729 (351)	631 (221)	–	–	651 (358)	644 (177)	587 (311)	572 (205)
nwt (minutes/week)	4990 (538)	4330 (671)	4810 (660)	4380 (596)	–	–	4920 (535)	4400 (561)	4990 (700)	4540 (600)
GPAQ MVPA (minutes/week)	988 (1020)	980 (1230)	1200 (1020)	995 (860)	1430 (954)	1410 (1270)	1160 (1380)	725 (687)	1170 (1080)	869 (644)
FVI diary (portions/week)	20.7 (14.5)	20.1 (11.6)	18.0 (11.8)	19.7 (10.8)	–	–	21.5 (13.1)	20.5 (10.0)	22.0 (13.3)	24.0 (10.1)
FVI quest (portions/week)	19.3 (11.0)	15.8 (11.8)	17.5 (11.2)	17.0 (12.2)	19.2 (12.2)	16.8 (9.96)	20.9 (14.7)	17.8 (11.3)	20.0 (15.1)	20.7 (11.3)
health	4.20 (0.808)	3.70 (0.803)	4.17 (1.11)	3.79 (0.645)	4.33 (0.816)	3.79 (0.592)	4.26 (0.828)	3.91 (0.946)	4.11 (1.04)	4.00 (0.799)
M intrinsic PA (RAI)	35.3 (14.1)	32.8 (18.8)	35.6 (13.0)	35.5 (17.4)	36.2 (14.7)	40.2 (12.9)	34.7 (14.7)	36.4 (12.6)	32.3 (18.4)	34.9 (13.5)
M intrinsic NU (RAI)	9.86 (19.7)	20.0 (17.9)	8.94 (19.1)	2.90 (11.7)	12.5 (20.6)	23.5 (18.9)	11.6 (19.0)	22.0 (15.7)	10.5 (20.7)	5.34 (10.5)

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

int PA	1.94 (1.02)	2.44 (1.22)	1.96 (0.932)	2.10 (1.25)	2.18 (1.07)	1.94 (0.886)	2.08 (0.997)	2.11 (0.934)	1.98 (0.917)	2.04 (0.922)
int NU	2.78 (0.840)	2.72 (0.854)	2.66 (0.939)	2.81 (0.890)	2.73 (0.719)	2.74 (0.790)	2.57 (0.855)	2.79 (0.793)	2.37 (0.878)	2.88 (0.761)
int app PA	2.68 (1.49)	3.19 (1.20)	2.96 (1.28)	3.00 (1.27)	2.94 (1.46)	3.35 (1.30)	3.10 (1.47)	3.47 (1.26)	3.09 (1.24)	3.04 (1.24)
int app NU	2.28 (1.23)	2.72 (1.32)	2.38 (1.24)	2.88 (1.25)	2.55 (1.30)	2.85 (1.28)	2.96 (1.39)	2.94 (1.25)	2.80 (1.31)	2.58 (1.13)
FHC NU	51.6 (7.41)	51.7 (7.01)	50.0 (8.39)	51.0 (7.08)	51.5 (7.46)	51.1 (7.30)	50.6 (8.06)	51.6 (8.82)	48.8 (9.52)	50.0 (8.88)
FHC PA	39.0 (7.92)	39.7 (7.63)	38.6 (8.03)	38.7 (7.32)	39.2 (8.37)	40.1 (7.35)	38.2 (7.91)	38.2 (8.33)	38.5 (7.54)	36.9 (7.78)
self-efficacy NU (RAI)	12.0 (3.52)	12.9 (4.23)	12.0 (3.22)	13.0 (3.19)	12.7 (4.13)	12.8 (2.97)	13.4 (3.52)	13.6 (2.84)	12.5 (3.67)	14.2 (2.95)
self-efficacy PA (RAI)	13.6 (3.71)	12.8 (3.53)	13.5 (3.11)	12.7 (3.35)	12.6 (3.53)	13.2 (3.11)	14.6 (2.71)	14.0 (3.04)	13.4 (3.22)	13.0 (3.25)
joint PA	2.00 (3.40)	1.84 (2.85)	3.69 (5.31)	3.03 (4.00)	5.12 (8.24)	3.58 (3.72)	0.960 (1.48)	1.19 (1.78)	3.97 (5.29)	3.08 (4.15)
joint NU	7.52 (4.39)	8.95 (4.26)	9.96 (3.13)	9.54 (2.78)	13.5 (6.00)	14.1 (4.64)	8.20 (5.54)	7.62 (4.67)	9.32 (5.79)	9.83 (5.16)

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

All control variables (except non-weartime for MVPA and steps, and population for FVI diary) improved the model fit based on AIC and were therefore included in the final sensitivity models with the exception of the joint models where only population improved the model fit. Random slopes were not supported by the data but random intercepts were used for all models. Sensitivity analysis showed no difference in patterns for the effectiveness of the intervention (see Appendix C, Tables 1-7). Therefore, only the main models are reported. Data and code are available at the Open Science Framework: https://osf.io/3gtja/

Effect of the intervention on physical activity

Results of the linear mixed models indicate significant main effects for the interaction of group with time in device-based-measured MVPA between T_0 and T_1 in favor of the control group (p = .016, β = -0.50). Steps show no significant main effect but the β point in the same direction as for device-based measured MVPA. Self-reported MVPA with the GPAQ reveals no significant interaction of group x time but a significant time effect between T_0 and T_2 (p = .008, β = 0.21). For all main results see Appendix B, Tables 1-3. Figures 2 and 3 display the descriptive results for the device-based measured PA outcomes MVPA and step count. As displayed by the grey dotted lines in Figure 2, both mean and median values are clearly above the recommendation for MVPA [4] for both children (i.e. 60 minutes per day on average, 420 minutes / week) and adults (i.e. 150 minutes / week) in both groups and at both measurement periods. For steps, mean and median values are below the commonly used 10.000 steps/day (70.000 steps/week) goal [91,92] for all participants (see Figure 3).

--- please insert Figure 2 here ---

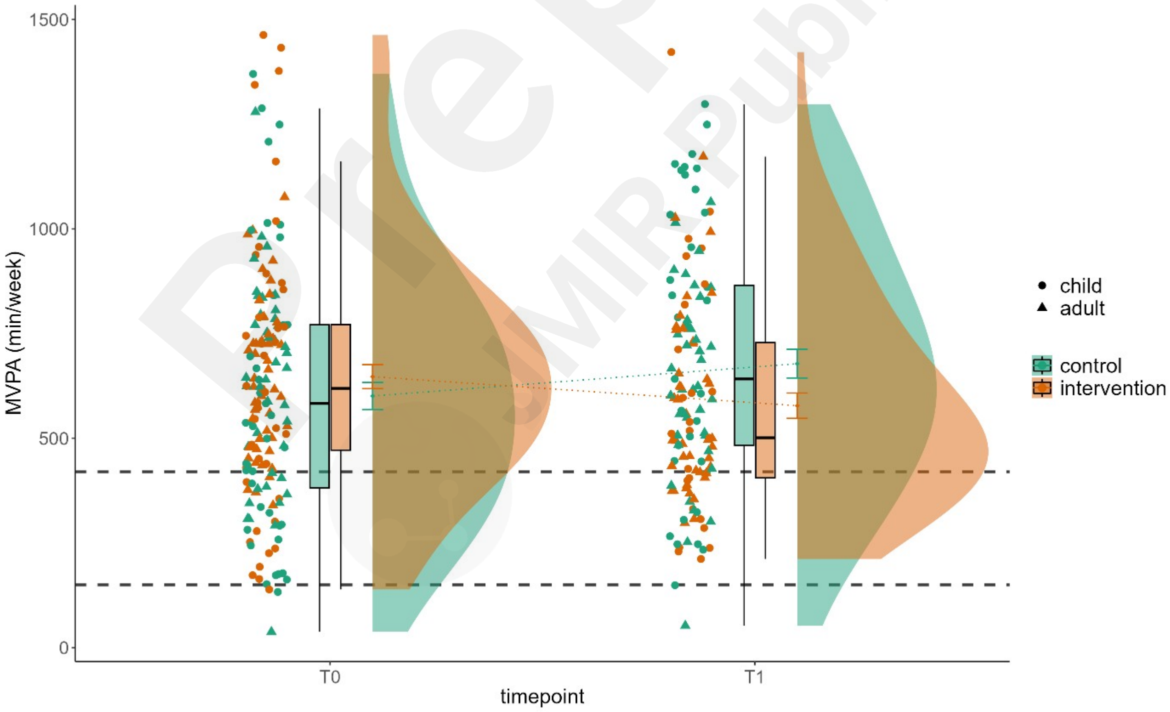


Figure 2. Interaction effect of group x time for device-based measured physical activity for the parameter minutes of moderate to vigorous physical activity per week (MVPA). Displayed is the mean MVPA (y-axis) of 180 participants during one week of baseline measurement (T_0) and one week of post-measurement after a 3-week intervention/waiting period (T_1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed lines represent the PA

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

recommendations for children (420 min/week) and adults (150 min/week).

--- please insert Figure 3 here ---

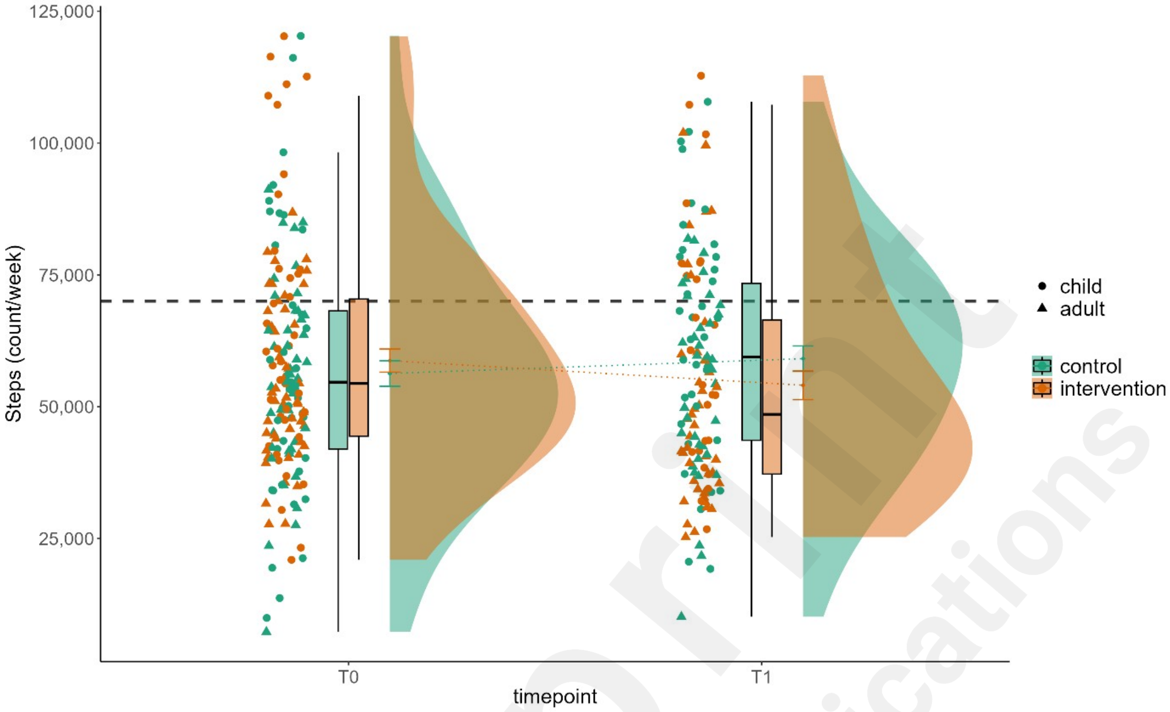


Figure 3. Interaction effect of group x time for device-based measured physical activity for the parameter steps per week (steps). Displayed is the mean step count (y-axis) of 180 participants during one week of baseline measurement (T_0) and one week of post-measurement after a 3-week intervention/waiting period (T_1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the commonly used step recommendation of 10.000 steps/day (70.000 steps/week).

Effect of the intervention on fruit and vegetable intake

Results of the linear mixed models indicate a significant interaction of group x time concerning FVI reported by the diary between T_0 and T_1 in favor of the intervention group (p = .031, β = -0.35). There is no significant main effect for FVI assessed via questionnaire (see Appendix B, Tables 4-5). Figure 4 displays the descriptive results for self-reported FVI per week assessed by the questionnaire. Here, both mean and median values are clearly below the recommended FVI of 5 portions per day (35 portions/week) [93].

--- please insert Figure 4 here ---

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

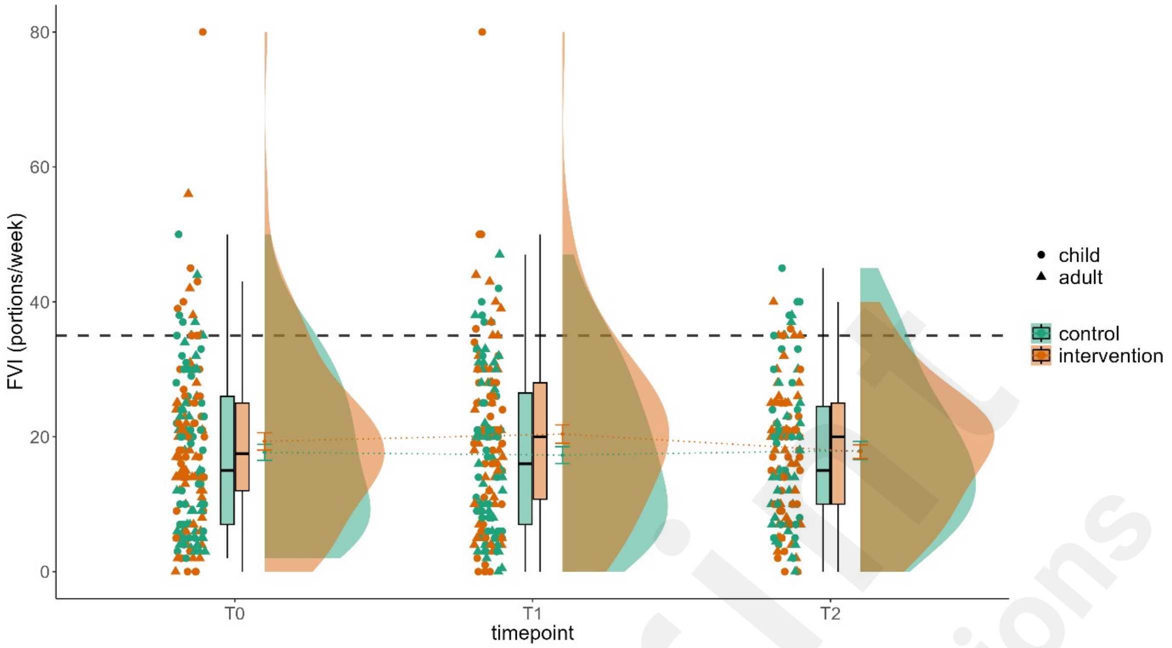


Figure 4. Interaction effect of group x time for the parameter fruit and vegetable intake per week (FVI) assessed by questionnaire. Displayed is the mean fruit and vegetable intake (y-axis) of 197 participants related to the week of baseline measurement (T_0), the week of post-measurement after a 3-week intervention/waiting period (T_1), and the week of follow-up measurement (T_2) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the recommendation for daily FVI of 5 portions (35 portions/week).

Effect of the intervention on joint Physical Activity and Meals

Results of the linear models indicate a significant effect for group x time for both T_0 to T_1 ($p = .026$, $\beta = 0.18$) and to T_2 ($p = .008$, $\beta = 0.29$) in favor of the intervention group for joint PA. Regarding joint meals, a significant group x time interaction was found for T_0 to T_1 in favor of the IG ($p = .004$, $\beta = 0.14$), and a significant group x time interaction was found for T_0 to T_2 in favor of the CG ($p < .001$, $\beta = -0.34$). Additionally, all four time effects were significant with a β between 0.21 and 1.20. All results are displayed in Appendix B, Tables 6 and 7.

Discussion

The SMART*FAMILY*2.0 trial evaluated the effectiveness of a refined mHealth intervention to increase PA and HE in a family setting. Extending previous research, the behavior of children *and* parents was targeted to induce individual behavior changes that are anchored in daily family life. Moreover, besides a theoretical foundation, several BCTs were additionally included which contribute to the fulfillment of basic psychological needs according to the self-determination theory [94]. Overall, there was no significant intervention effect of our app for PA, independent of measurement method, but for FVI as measured by diary. However, participants were not able to maintain this effect four weeks after intervention cessation. The explorative results for joint PA point to a potential effectiveness of the collaborative mHealth intervention.

PA and HE

Regarding PA results it is noteworthy that an interaction effect occurred for device-

based measured MVPA in favour of the control group, and the same tendency was found in the steps measure. On the first sight this seems arbitrary. However, a closer look to the data reveals that the sample was already highly active at baseline, however coincidentially just as low regarding their FVI. Regarding guideline adherence, participants exceeded the recommended amount of 420 minutes of MVPA per week by 180 minutes on average, but simultaneously deceeded the recommended amount of 35 portions of fruits and vegetables by 15 (diary) or 17.5 (questionnaire). Whereas our sample can be classified as being highly active in an (inter-) national comparison [95] [94], they cannot be classified as equally healthy regarding their eating behavior. In a germanwide representative sample, 17% (7%) of 6- to 11-year-olds and 20% (23%) of 12- to 17-year-olds reached the recommendation on fruit (vegetable) consumption [14,96]. Our intervention was able to evoke a positive intervention effect on FVI based on diaries, as there was enough room for improvement in contrast to PA levels. Surprisingly, this effect was not present in FVI assessed via questionnaires. This elucidades the need to interpret findings with caution regarding measurement accuracy and construct validity. Research shows that the same construct measured with different methods is likely to lead to different results [97,98], and a comparison within the current data shows a limited comparability between device-based and self-reported measures[77,78]. Additionally, a secondary data analysis on the JITAI within the intervention group of this study points to promising results concerning physical activity enhancement in the subsequent hour after a prolonged period of inactivity [66]. This points to the importance of considering the timeframe and aim of the intervention as this enhancement on an hour to hour analysis that is also important for health benefits [99] is not detectable if considering pre- posttest analyses on a weekly level. Moreover, the different findings regarding PA and FVI supports the notion that both health behaviors must be viewed and targeted independently in interventions, as they do not seem to be related.
In contrast to MVPA and step findings, joint PA within the family revealed a positive intervention effect, i.e. our app supported the families to be active together. This results show that it is of importance to interpret the quality of PA in addition to the amount and intensity. Studies have found the positive influence of social interaction for habit formation [100,101]. Hence it is of high importance to facilitate family events of PA to teach children and adolescents the fun and enjoyment of PA in social groups. For joint meals, however, the effect of T_0 to T_1 was in favor of the IG, and for T_0 to T_2 was in favor of the CG, but an increase over time was observable in all groups.

Taken together, the hypothesis that HE would increase due to the intervention was supported by diary data. For PA, no or even a partially reversed intervention effect could be detected. However, this is in line with previous digital health studies also revealing heterogeneous results with a majority of studies finding at least some significant benefit of interventions [50,53]. However, it needs to be noted that the current sample was exceedingly high in their amount of PA, however coincidentially just as low regarding their FVI.

Family-based interventions

Research on mHealth interventions for families is scarce, particularly those involving randomized controlled trials (RCTs). Existing studies often focus on digital interventions between parents and children, but the results are mixed and sometimes combined with non-digital approaches. These studies tend to emphasize children's behavior rather than considering the entire family [102,103]. A recent review highlighted the effectiveness of digital interventions in preventing childhood obesity, with only two of the included studies specifically addressing mobile health interventions [104]. In one study, an app for self-monitoring weight and goal-setting led to greater weight reduction compared to standard care after 6 months in children with obesity [105]. Another study aimed to enhance fundamental movement skills in 3- to 6-year-olds and observed improvements after a 2-month intervention period [106]. However, not all studies reported positive effects. Of the seven studies included in another review [107], two pilot studies reported significant improvements in PA, three studies found evidence for some improvements in PA measures, e.g. collaborative PA of children and parents, and the remaining two studies found no evidence for an effect. Interestingly, one study found that adolescent dropout rates were more than 12 times higher when parents stopped using the application. In this regard, analyzing family-behavior and dyadic relationships will be a promising approach for future investigations. Studies suggest that family meal practices and values can support HE [108] [101] and that the frequency of shared family meals is significantly related to nutritional health in children and adolescents [31]. The current results do not support the assumption that joint PA or joint meals (i.e. some kind of “quality time” within the family) impacts quantitative PA or HE behavior. However, it needs to be acknowledged that joint PA was rather low in our sample (only about 1 joint activity per week), and the enjoyment of PA or attitude towards PA were no outcome variables in the current trial.

Strengths and limitations

The main strengths of the SMART*FAMILY*2.0 intervention are that (1) it collaboratively targets the family, (2) it is designed as a cluster randomized controlled trial, (3) it is theory-based, and (4) it incorporates 14 different BCTs, four more than the prior version of the app. Further, (5) the goalsetting in the app is ad libitum selected by the family to fit their schedule and preferences with guidance from the results of the first measurement week. This empowers the families to set self-selected goals which have been found to increase motivation and adherence [109,110]. In this recent app version, (6) JITAIs were included to change behaviour when participants were most prone to [64–66], and (7) gamification features were expanded through an avatarized coach, asking questions for (8) ecological momentary assessment, providing support with goal-setting challenges and providing health literacy information. Another strength regarding the evaluation is (9) that multiple outcome measures of self-reported and device-based measured PA were considered. This is important as these measures are known to yield different results, and including multiple measurement tools improves the plausibility of the results [77,111]. Last, using (10) advanced statistical methods to consider the nested structure of the data by applying multilevel analyses enhanced the accuracy of the results, as it considered the variance based on the clustering of participants in families.

Some limitations have to be acknowledged. Regarding our sample, family sizes and ages within families have been very diverse while the required sample size by the a priory power analysis of 52 families and 156 participants has been met [71]. However, there is a lack of knowledge about how these composite family structures interfere with results regarding behavior change or the accomplishment of healthy lifestyles. For example, it might be assumed that older parents might be more aware of healthy food choices, as they consider healthy nutrition as being more important for themselves than their younger counterparts [112]. Advanced paternal age is associated with increased risk, and younger paternal age with decreased risk of children’s eating disorders [113]. A further restriction might be the age range, especially for children and adolescents. Since this study includes the whole family, children of different ages and with different needs and perceptions were addressed similarly by the app which might have affected intervention effects. Future interventions should aim to address the individual needs of the family members and tailor the intervention more specifically to the participants. Another important factor concerning the current sample, which could explain the lack of significant intervention effects for PA was probably the highly active sample with around 600 minutes of MVPA per week and person, which already fulfilled the guidelines of the World Health Organisation for PA [4]. This is in contrast to recent research about PA guideline fulfillment, which reliably reveals only small portions of participants fulfilling the PA recommendations, with lower amounts with increasing ages [9–11]. This skewness of our sample was also apparent regarding body composition and HE behaviour [114]. With BMIs between 17 and 19 in children, and between 23 and 27 in adults, our sample was of normal weight. Studies have shown that intervention effects can be expected to be higher on overweight or obese samples, both for HE and PA interventions [115]. This might be a probable explanation for the absence of intervention effects (i.e., there was no or only little room for improvement in our sample).

An additional aspect was that the participants had to use the provided smartphones instead of their own for equality and data security reasons, which can be burdensome. However, previous research showed no differences in engagement between participants with their own smartphones versus additional smartphones [116]. If a program aims for long-term sustainability beyond a scientific scope, the use of an additional phone must be considered very carefully.

Another potentially limiting factor is the comparably short duration of the intervention. Based on literature regarding behavior change theories (i.e. the transtheoretical model [117], an intervention duration of three weeks might not have been sufficient [50]. However, mHealth intervention studies even revealed significant behavior change effects with intervention durations of only one [118], two [119], and three weeks [120]. In a similar vein, a recent meta-analysis on mobile apps for diet showed that interventions with longer duration were not generally more effective [121].

Moreover, as we examined families in their natural setting, there are also practical constraints. In Germany, a continuous school period lasts a maximum of 6 to 8 weeks, followed by a vacation period. To conduct the core assessments including pre- and post-testing accelerometry (please see also Fig. 1, study design) during one continuous school period, an intervention period longer than three weeks was not feasible for the study design. Longer intervention periods would inevitably mean that there is a co-founding between the assessment period (school time vs. vacation). Furthermore, data was gathered during the Covid-19 pandemic. However, we did not test any participants within lockdown situation, i.e. where they were not allowed to leave the house. However, homeschooling and homeoffice might have influenced the results, both in children and adults. Especially in Germany, research showed that Covid-19 hightened the amount of PA in children and adolescents [111], depending on population density [122]. Independent of age, gender and country, however, a declining trend in PA was found [123].

Conclusion

Taken together, the evaluation of the SMART*FAMILY2.0* trial expands the existing body of evidence as it investigated the influence of a theory-based mHealth intervention targeting PA and HE in a collective family-based setting. Yet, no evidence for the effectiveness of the trial has been found for PA, but diary data of HE, and joint PA showed improvements due to app usage. The finding regarding PA, might be attributable to an initially active and lean sample. Future evaluations of interventions should therefore also consider (1) methods that go beyond pre-post-follow-up designs to account for the timeliness and complexity of mHealth interventions, (2) recruiting participants of all activity- and weight levels, and (3) control for or restrict ages of children and parents.

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

Figure Captions

Figure 1. Detailed study design.
Figure 2. Interaction effect of group x time for device-based measured physical activity for the parameter minutes of moderate to vigorous physical activity per week (MVPA). Displayed is the mean MVPA (y-axis) of 180 participants during one week of baseline measurement (T_0) and one week of post-measurement after a 3-week intervention/waiting period (T_1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed lines represent the PA recommendations for children (420 min/week) and adults (150 min/week).

Figure 3. Interaction effect of group x time for device-based measured physical activity for the parameter steps per week (steps). Displayed is the mean step count (y-axis) of 180 participants during one week of baseline measurement (T_0) and one week of post-measurement after a 3-week intervention/waiting period (T_1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the commonly used step recommendation of 10.000 steps/day (70.000 steps/week).

Figure 4. Interaction effect of group x time for the parameter fruit and vegetable intake per week (FVI) assessed by questionnaire. Displayed is the mean fruit and vegetable intake (y-axis) of 197 participants related to the week of baseline measurement (T_0), the week of post-measurement after a 3-week intervention/waiting period (T_1), and the week of follow-up measurement (T_2) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the recommendation for daily FVI of 5 portions (35 portions/week).

Appendix

Appendix A. Consort eHealth checklist.
Appendix B. Results of the main analyses.
Appendix C. Results of the sensitivity analyses.

References

1. Biddle SJH, Gorely T, Stensel DJ. Health-enhancing physical activity and sedentary behaviour in children and adolescents. J Sports Sci 2004 Aug;22(8):679–701. PMID:15370482

2. Warburton DER. Health benefits of physical activity: the evidence. Canadian Medical Association Journal 2006 Mar 14;174(6):801–809. doi: 10.1503/cmaj.051351

3. Van Duyn MA, Pivonka E. Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: selected literature. J Am Diet Assoc 2000 Dec;100(12):1511–1521. PMID:11138444

4. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput J-P, Chastin S, Chou R, Dempsey PC, DiPietro L, Ekelund U, Firth J, Friedenreich CM, Garcia L, Gichu M, Jago R, Katzmarzyk PT, Lambert E, Leitzmann M, Milton K, Ortega FB, Ranasinghe C, Stamatakis E, Tiedemann A, Troiano RP, van der Ploeg HP, Wari V, Willumsen JF. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med 2020 Dec;54(24):1451–1462. PMID:33239350

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

5. Bamman MM, Cooper DM, Booth FW, Chin ER, Neufer PD, Trappe S, Lightfoot JT, Kraus WE, Joyner MJ. Exercise biology and medicine: innovative research to improve global health. Mayo Clin Proc 2014 Feb;89(2):148–153. PMID:24485128

6. Neufer PD, Bamman MM, Muoio DM, Bouchard C, Cooper DM, Goodpaster BH, Booth FW, Kohrt WM, Gerszten RE, Mattson MP, Hepple RT, Kraus WE, Reid MB, Bodine SC, Jakicic JM, Fleg JL, Williams JP, Joseph L, Evans M, Maruvada P, Rodgers M, Roary M, Boyce AT, Drugan JK, Koenig JI, Ingraham RH, Krotoski D, Garcia-Cazarin M, McGowan JA, Laughlin MR. Understanding the Cellular and Molecular Mechanisms of Physical Activity-Induced Health Benefits. Cell Metabolism 2015 Jul 7;22(1):4–11. doi: 10.1016/j.cmet.2015.05.011

7. Owen N, Healy GN, Matthews CE, Dunstan DW. Too Much Sitting: The Population-Health Science of Sedentary Behavior. Exerc Sport Sci Rev 2010 Jul;38(3):105–113. PMID:20577058

8. Bourke M, Haddara A, Loh A, Carson V, Breau B, Tucker P. Adherence to the World Health Organization's physical activity recommendation in preschool-aged children: a systematic review and meta-analysis of accelerometer studies. International Journal of Behavioral Nutrition and Physical Activity 2023 Apr 26;20(1):52. doi: 10.1186/s12966-023-01450-0

9. Janssen I. Physical Activity Epidemiology. The Oxford handbook of exercise psychology New York: Oxford University Press; 2012.

10. Aubert S, Brazo-Sayavera J, González SA, Janssen I, Manyanga T, Oyeyemi AL, Picard P, Sherar LB, Turner E, Tremblay MS. Global prevalence of physical activity for children and adolescents; inconsistencies, research gaps, and recommendations: a narrative review. Int J Behav Nutr Phys Act 2021 Jun 29;18(1):81. doi: 10.1186/s12966-021-01155-2

11. Tapia-Serrano MA, Sevil-Serrano J, Sánchez-Miguel PA, López-Gil JF, Tremblay MS, García-Hermoso A. Prevalence of meeting 24-Hour Movement Guidelines from pre-school to adolescence: A systematic review and meta-analysis including 387,437 participants and 23 countries. Journal of Sport and Health Science 2022 Jul 1;11(4):427–437. doi: 10.1016/j.jshs.2022.01.005

12. McArthur BA, Volkova V, Tomopoulos S, Madigan S. Global Prevalence of Meeting Screen Time Guidelines Among Children 5 Years and Younger: A Systematic Review and Meta-analysis. JAMA Pediatr 2022 Apr 1;176(4):373–383. PMID:35157028

13. Friel CP, Duran AT, Shechter A, Diaz KM. U.S. Children Meeting Physical Activity, Screen Time, and Sleep Guidelines. American Journal of Preventive Medicine 2020 Oct 1;59(4):513–521. doi: 10.1016/j.amepre.2020.05.007

14. Nielsen SJ, Rossen LM, Harris DM, Odgen CL. Fruit and vegetable consumption of U.S. Youth, 2009-2010. NCHS Data Brief 2014 Jul;(156):1–8. PMID:25027507

15. Walther J, Aldrian U, Stüger HP, Kiefer I, Ekmekcioglu C. Nutrition, lifestyle factors, and mental health in adolescents and young adults living in Austria. Int J Adolesc Med Health 2014;26(3):377–386. PMID:24803606

16. Powell PK, Durham J, Lawler S. Food Choices of Young Adults in the United States of America: A Scoping Review. Advances in Nutrition Elsevier; 2019 May 1;10(3):479–488. PMID:31093651

17. Heerman WJ, Jackson N, Hargreaves M, Mulvaney SA, Schlundt D, Wallston KA, Rothman RL. Clusters of Healthy and Unhealthy Eating Behaviors are Associated with Body Mass Index Among Adults. J Nutr Educ Behav 2017 May;49(5):415-421.e1. PMID:28363804

18. Waxman A, World Health Assembly. WHO global strategy on diet, physical activity and health. Food Nutr Bull 2004 Sep;25(3):292–302. PMID:15460274

19. Granger E, Di Nardo F, Harrison A, Patterson L, Holmes R, Verma A. A systematic review of the relationship of physical activity and health status in adolescents. Eur J Public Health 2017 May

1;27(suppl_2):100–106. PMID:28340201

20. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN. Sedentary Behaviors Increase Risk of Cardiovascular Disease Mortality in Men. Med Sci Sports Exerc 2010 May;42(5):879–885. PMID:19996993

21. Penedo FJ, Dahn JR. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. Curr Opin Psychiatry 2005 Mar;18(2):189–193. PMID:16639173

22. Bechthold A, Boeing H, Schwedhelm C, Hoffmann G, Knüppel S, Iqbal K, De Henauw S, Michels N, Devleesschauwer B, Schlesinger S, Schwingshackl L. Food groups and risk of coronary heart disease, stroke and heart failure: A systematic review and dose-response meta-analysis of prospective studies. Critical Reviews in Food Science and Nutrition Taylor & Francis; 2019 Apr 12;59(7):1071–1090. PMID:29039970

23. Lee I-M. Dose-Response Relation Between Physical Activity and FitnessEven a Little Is Good; More Is Better. JAMA 2007 May 16;297(19):2137–2139. doi: 10.1001/jama.297.19.2137

24. Malina RM. Tracking of physical activity and physical fitness across the lifespan. Res Q Exerc Sport 1996 Sep;67(3 Suppl):S48-57. PMID:8902908

25. Andersen LB, Haraldsdóttir J. Tracking of cardiovascular disease risk factors including maximal oxygen uptake and physical activity from late teenage to adulthood. An 8-year follow-up study. J Intern Med 1993 Sep;234(3):309–315. PMID:8354982

26. Raitakari OT, Porkka KV, Taimela S, Telama R, Räsänen L, Viikari JS. Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. The Cardiovascular Risk in Young Finns Study. Am J Epidemiol 1994 Aug 1;140(3):195–205. PMID:8030623

27. Twisk JW, Van Mechelen W, Kemper HC, Post GB. The relation between “long-term exposure” to lifestyle during youth and young adulthood and risk factors for cardiovascular disease at adult age. J Adolesc Health 1997 Apr;20(4):309–319. PMID:9098736

28. Fogelholm M. How physical activity can work? Int J Pediatr Obes 2008;3 Suppl 1:10–14. PMID:18278627

29. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. Am J Prev Med 2005 Apr;28(3):267–273. PMID:15766614

30. Umberson D, Crosnoe R, Reczek C. Social Relationships and Health Behavior Across Life Course. Annu Rev Sociol 2010 Aug 1;36:139–157. PMID:21921974

31. Lawler M, Heary C, Nixon E. Peer Support and Role Modelling Predict Physical Activity Change among Adolescents over Twelve Months. J Youth Adolescence 2020 Jul 1;49(7):1503–1516. doi: 10.1007/s10964-019-01187-9

32. Neumark-Sztainer D, MacLehose R, Loth K, Fulkerson JA, Eisenberg ME, Berge J. What’s for dinner? Types of food served at family dinner differ across parent and family characteristics. Public Health Nutr 2014 Jan;17(1):145–155. PMID:23083836

33. Viner RM, Ozer EM, Denny S, Marmot M, Resnick M, Fatusi A, Currie C. Adolescence and the social determinants of health. Lancet 2012 Apr 28;379(9826):1641–1652. PMID:22538179

34. Dozier SGH, Schroeder K, Lee J, Fulkerson JA, Kubik MY. The Association between Parents and Children Meeting Physical Activity Guidelines. Journal of Pediatric Nursing 2020 May 1;52:70–75. doi: 10.1016/j.pedn.2020.03.007

35. Berge JM. A review of familial correlates of child and adolescent obesity: what has the 21st century taught us so far? Int J Adolesc Med Health 2009;21(4):457–483. PMID:20306760

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

36. Hammons AJ, Fiese BH. Is frequency of shared family meals related to the nutritional health of children and adolescents? Pediatrics 2011 Jun;127(6):e1565-1574. PMID:21536618

37. Dallacker M, Hertwig R, Mata J. The frequency of family meals and nutritional health in children: a meta-analysis. Obes Rev 2018 May;19(5):638–653. PMID:29334693

38. Dishman RK, Sallis JF, Orenstein DR. The determinants of physical activity and exercise. Public Health Rep 1985;100(2):158–171. PMID:3920714

39. Martin JE, Dubbert PM. Exercise applications and promotion in behavioral medicine: current status and future directions. J Consult Clin Psychol 1982 Dec;50(6):1004–1017. PMID:7174968

40. van Sluijs EMF, Kriemler S, McMinn AM. The effect of community and family interventions on young people's physical activity levels: a review of reviews and updated systematic review. Br J Sports Med 2011 Sep;45(11):914–922. PMID:21836175

41. Coughlin SS, Whitehead M, Sheats JQ, Mastromonico J, Smith S. A Review of Smartphone Applications for Promoting Physical Activity. Jacobs J Community Med 2016;2(1):021. PMID:27034992

42. Lindsay Smith G, Banting L, Eime R, O'Sullivan G, van Uffelen JGZ. The association between social support and physical activity in older adults: a systematic review. International Journal of Behavioral Nutrition and Physical Activity 2017 Apr 27;14(1):56. doi: 10.1186/s12966-017-0509-8

43. Murphy JK, Williamson DA, Buxton AE, Moody SC, Absher N, Warner M. The long-term effects of spouse involvement upon weight loss and maintenance. Behavior Therapy 1982 Nov 1;13(5):681–693. doi: 10.1016/S0005-7894(82)80024-5

44. Dubbert PM, Wilson GT. Goal-setting and spouse involvement in the treatment of obesity. Behav Res Ther 1984;22(3):227–242. PMID:6466273

45. Brownell KD, Heckerman CL, Westlake RJ, Hayes SC, Monti PM. The effect of couples training and partner co-operativeness in the behavioral treatment of obesity. Behaviour Research and Therapy 1978 Jan 1;16(5):323–333. doi: 10.1016/0005-7967(78)90002-5

46. Vandelanotte C, Müller AM, Short CE, Hingle M, Nathan N, Williams SL, Lopez ML, Parekh S, Maher CA. Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. J Nutr Educ Behav 2016 Mar;48(3):219-228.e1. PMID:26965100

47. Issues in mHealth: findings from key informant interviews - PubMed. Available from: https://pubmed.ncbi.nlm.nih.gov/23032424/ [accessed Jul 26, 2024]

48. König LM, Sproesser G, Schupp HT, Renner B. Describing the Process of Adopting Nutrition and Fitness Apps: Behavior Stage Model Approach. JMIR Mhealth Uhealth 2018 Mar 13;6(3):e55. PMID:29535078

49. Iribarren SJ, Cato K, Falzon L, Stone PW. What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions. PLoS One 2017;12(2):e0170581. PMID:28152012

50. Villinger K, Wahl DR, Boeing H, Schupp HT, Renner B. The effectiveness of app-based mobile interventions on nutrition behaviours and nutrition-related health outcomes: A systematic review and meta-analysis. Obesity Reviews 2019;20(10):1465–1484. doi: 10.1111/obr.12903

51. Schoeppe S, Alley S, Van Lippevelde W, Bray NA, Williams SL, Duncan MJ, Vandelanotte C. Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. Int J Behav Nutr Phys Act 2016 Dec 7;13(1):127. PMID:27927218

52. Baumann H, Fiedler J, Wunsch K, Woll A, Wollesen B. mHealth Interventions to Reduce Physical Inactivity and Sedentary Behavior in Children and Adolescents: Systematic Review and Meta-

analysis of Randomized Controlled Trials. JMIR Mhealth Uhealth 2022 May 11;10(5):e35920. PMID:35544294

53. Fiedler J, Eckert T, Wunsch K, Woll A. Key facets to build up eHealth and mHealth interventions to enhance physical activity, sedentary behavior and nutrition in healthy subjects – an umbrella review. BMC Public Health 2020 Oct 23;20(1):1605. doi: 10.1186/s12889-020-09700-7

54. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. Psychology & Health Routledge; 2011 Nov 1;26(11):1479–1498. PMID:21678185

55. Webb T, Joseph J, Yardley L, Michie S. Using the Internet to Promote Health Behavior Change: A Systematic Review and Meta-analysis of the Impact of Theoretical Basis, Use of Behavior Change Techniques, and Mode of Delivery on Efficacy. Journal of Medical Internet Research 2010 Feb 17;12(1):e1376. doi: 10.2196/jmir.1376

56. Prestwich A, Sniehotta FF, Whittington C, Dombrowski SU, Rogers L, Michie S. Does theory influence the effectiveness of health behavior interventions? Meta-analysis. Health Psychol 2014 May;33(5):465–474. PMID:23730717

57. Morrison J, Pikhart H, Ruiz M, Goldblatt P. Systematic review of parenting interventions in European countries aiming to reduce social inequalities in children's health and development. BMC Public Health 2014 Oct 6;14:1040. PMID:25287010

58. Schoeppe S, Alley S, Rebar AL, Hayman M, Bray NA, Van Lippevelde W, Gnam J-P, Bachert P, Direito A, Vandelanotte C. Apps to improve diet, physical activity and sedentary behaviour in children and adolescents: a review of quality, features and behaviour change techniques. Int J Behav Nutr Phys Act 2017 Jun 24;14(1):83. PMID:28646889

59. Wunsch K, Fiedler J, Hubenschmid S, Reiterer H, Renner B, Woll A. An mHealth Intervention Promoting Physical Activity and Healthy Eating in a Family Setting (SMARTFAMILY): Randomized Controlled Trial. JMIR mHealth and uHealth 2024 Apr 26;12(1):e51201. doi: 10.2196/51201

60. Mazeas A, Duclos M, Pereira B, Chalabaev A. Evaluating the Effectiveness of Gamification on Physical Activity: Systematic Review and Meta-analysis of Randomized Controlled Trials. Journal of Medical Internet Research 2022 Jan 4;24(1):e26779. doi: 10.2196/26779

61. Nezondet C, Gandrieau J, Bourrelier J, Nguyen P, Zunquin G. The Effectiveness of a Physical Literacy-Based Intervention for Increasing Physical Activity Levels and Improving Health Indicators in Overweight and Obese Adolescents (CAPACITES 64). Children Multidisciplinary Digital Publishing Institute; 2023 Jun;10(6):956. doi: 10.3390/children10060956

62. Carl J, Barratt J, Wanner P, Töpfer C, Cairney J, Pfeifer K. The Effectiveness of Physical Literacy Interventions: A Systematic Review with Meta-Analysis. Sports Med 2022 Dec 1;52(12):2965–2999. doi: 10.1007/s40279-022-01738-4

63. Dunton GF. Ecological Momentary Assessment in Physical Activity Research. Exercise and Sport Sciences Reviews 2017 Jan;45(1):48. doi: 10.1249/JES.0000000000000092

64. Wunsch K, Eckert T, Fiedler J, Woll A. Just-in-time adaptive interventions in mobile physical activity interventions- A synthesis of frameworks and future directions. European Health Psychologist 2022 Apr 22;22(4):834–842.

65. Nahum-Shani I, Smith SN, Spring BJ, Collins LM, Witkiewitz K, Tewari A, Murphy SA. Just-in-Time Adaptive Interventions (JITAIs) in Mobile Health: Key Components and Design Principles for Ongoing Health Behavior Support. Ann Behav Med 2018 May 18;52(6):446–462. PMID:27663578

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

66. Fiedler J, Seiferth C, Eckert T, Woll A, Wunsch K. A just-in-time adaptive intervention to enhance physical activity in the SMARTFAMILY2.0 trial. Sport, Exercise, and Performance Psychology US: Educational Publishing Foundation; 2023;12(1):43–57. doi: 10.1037/spy0000311

67. Just-in-time adaptive interventions for behavior change in physiological health outcomes and the use case for knee osteoarthritis: a systematic review. JMIR Preprints. Available from: https://preprints.jmir.org/preprint/54119 [accessed Aug 5, 2024]

68. Hicks JL, Boswell MA, Althoff T, Crum AJ, Ku JP, Landay JA, Moya PML, Murnane EL, Snyder MP, King AC, Delp SL. Leveraging mobile technology for public health promotion: a multidisciplinary perspective. Annu Rev Public Health 2023 Apr 3;44:131–150. PMID:36542772

69. Gonul S, Namli T, Huisman S, Laleci Erturkmen GB, Toroslu IH, Cosar A. An expandable approach for design and personalization of digital, just-in-time adaptive interventions. Journal of the American Medical Informatics Association 2019 Mar 1;26(3):198–210. doi: 10.1093/jamia/ocy160

70. Hardeman W, Houghton J, Lane K, Jones A, Naughton F. A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity. Int J Behav Nutr Phys Act 2019 Apr 3;16(1):31. PMID:30943983

71. Wunsch K, Eckert T, Fiedler J, Cleven L, Niermann C, Reiterer H, Renner B, Woll A. Effects of a Collective Family-Based Mobile Health Intervention Called “SMARTFAMILY” on Promoting Physical Activity and Healthy Eating: Protocol for a Randomized Controlled Trial. JMIR Res Protoc 2020 Nov 11;9(11):e20534. PMID:33174849

72. Eysenbach G, Group C-E. CONSORT-EHEALTH: Improving and Standardizing Evaluation Reports of Web-based and Mobile Health Interventions. Journal of Medical Internet Research 2011 Dec 31;13(4):e1923. doi: 10.2196/jmir.1923

73. Anastasopoulou P. A comparison of two commercial activity monitors for measuring step counts. International journal of sports science and engineering 2013;7(1):S. 31-35.

74. Anastasopoulou P, Tubic M, Schmidt S, Neumann R, Woll A, Härtel S. Validation and Comparison of Two Methods to Assess Human Energy Expenditure during Free-Living Activities. PLOS ONE Public Library of Science; 2014 Feb 28;9(2):e90606. doi: 10.1371/journal.pone.0090606

75. Härtel S, Gnam J-P, Löffler S, Bös K. Estimation of energy expenditure using accelerometers and activity-based energy models—validation of a new device. Eur Rev Aging Phys Act BioMed Central; 2011 Oct;8(2):109–114. doi: 10.1007/s11556-010-0074-5

76. Armstrong T, Bull F. Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). J Public Health 2006 Apr 1;14(2):66–70. doi: 10.1007/s10389-006-0024-x

77. Fiedler J, Eckert T, Burchartz A, Woll A, Wunsch K. Comparison of Self-Reported and Device-Based Measured Physical Activity Using Measures of Stability, Reliability, and Validity in Adults and Children. Sensors Multidisciplinary Digital Publishing Institute; 2021 Jan;21(8):2672. doi: 10.3390/s21082672

78. Fiedler J, Woll A, Wunsch K. Comparison of Self-Reported and Device-Based Measured Physical Activity – a replication study. German Journal of Exercise and Sport Research in press;

79. DeSalvo KB, Fisher WP, Tran K, Bloser N, Merrill W, Peabody J. Assessing measurement properties of two single-item general health measures. Qual Life Res 2006 Mar;15(2):191–201. PMID:16468076

80. Markland D, Tobin V. A modification to the Behavioural Regulation in Exercise Questionnaire to include an assessment of amotivation. Journal of Sport & Exercise Psychology US: Human

Kinetics; 2004;26(2):191–196. doi: 10.1123/jsep.26.2.191

81. Pelletier LG, Dion SC, Slovinec-D'Angelo M, Reid R. Why Do You Regulate What You Eat? Relationships Between Forms of Regulation, Eating Behaviors, Sustained Dietary Behavior Change, and Psychological Adjustment. Motivation and Emotion 2004 Sep 1;28(3):245–277. doi: 10.1023/B:MOEM.0000040154.40922.14

82. Nigg CR. There is more to stages of exercise than just exercise. Exerc Sport Sci Rev 2005 Jan;33(1):32–35. PMID:15640718

83. Schwarzer R, Renner B. Health-Specific Self-Efficacy Scales.

84. Niermann C, Krapf F, Renner B, Reiner M, Woll A. Family health climate scale (FHC-scale): development and validation. International Journal of Behavioral Nutrition and Physical Activity 2014 Mar 5;11(1):30. doi: 10.1186/1479-5868-11-30

85. R: A language and environment for statistical computing [Computer software]. Available from: https://search.gesis.org/publication/zis-RCoreTeam.2021R [accessed Jul 26, 2024]

86. ggplot2: Elegant Graphics for Data Analysis (3e). Available from: https://ggplot2-book.org/ [accessed Jul 24, 2024]

87. Raincloud plots: a multi-platform tool for robust data visualization - PubMed. Available from: https://pubmed.ncbi.nlm.nih.gov/31069261/ [accessed Jul 26, 2024]

88. Kuznetsova A, Brockhoff PB, Christensen RHB. lmerTest Package: Tests in Linear Mixed Effects Models. Journal of Statistical Software 2017 Dec 6;82:1–26. doi: 10.18637/jss.v082.i13

89. Lüdecke D, Bartel A, Schwemmer C, Powell C, Djalovski A, Titz J. sjPlot: Data Visualization for Statistics in Social Science. 2024. Available from: https://cran.r-project.org/web/packages/sjPlot/index.html [accessed Jul 24, 2024]

90. Lüdecke D, Ben-Shachar MS, Patil I, Waggoner P, Makowski D. performance: An R Package for Assessment, Comparison and Testing of Statistical Models. Journal of Open Source Software 2021 Apr 21;6(60):3139. doi: 10.21105/joss.03139

91. Paluch AE, Bajpai S, Bassett DR, Carnethon MR, Ekelund U, Evenson KR, Galuska DA, Jefferis BJ, Kraus WE, Lee I-M, Matthews CE, Omura JD, Patel AV, Pieper CF, Rees-Punia E, Dallmeier D, Klenk J, Whincup PH, Dooley EE, Gabriel KP, Palta P, Pompeii LA, Chernofsky A, Larson MG, Vasan RS, Spartano N, Ballin M, Nordström P, Nordström A, Anderssen SA, Hansen BH, Cochrane JA, Dwyer T, Wang J, Ferrucci L, Liu F, Schrack J, Urbanek J, Saint-Maurice PF, Yamamoto N, Yoshitake Y, Newton RL, Yang S, Shiroma EJ, Fulton JE. Daily steps and all-cause mortality: a meta-analysis of 15 international cohorts. The Lancet Public Health Elsevier; 2022 Mar 1;7(3):e219–e228. PMID:35247352

92. Tudor-Locke C, Craig CL, Brown WJ, Clemes SA, De Cocker K, Giles-Corti B, Hatano Y, Inoue S, Matsudo SM, Mutrie N, Oppert J-M, Rowe DA, Schmidt MD, Schofield GM, Spence JC, Teixeira PJ, Tully MA, Blair SN. How many steps/day are enough? for adults. International Journal of Behavioral Nutrition and Physical Activity 2011 Jul 28;8(1):79. doi: 10.1186/1479-5868-8-79

93. Bedeutung von Obst und Gemüse in der Ernährung des Menschen. DGE. Available from: http://www.dge.de/wissenschaft/fachinformationen/bedeutung-von-obst-und-gemuese-in-der-ernaehrung-des-menschen/ [accessed Jul 26, 2024]

94. Ryan RM, Deci EL. Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. American Psychologist 2000;

95. Bann D, Scholes S, Fluharty M, Shure N. Adolescents' physical activity: cross-national comparisons of levels, distributions and disparities across 52 countries. International Journal of

Behavioral Nutrition and Physical Activity 2019 Dec 30;16(1):141. doi: 10.1186/s12966-019-0897-z

96. https://www.rki.de/EN/Content/Health_Monitoring/Health_Reporting/GBEDownloadsK/2011_6_fruit_vegetables.pdf?__blob=publicationFile. Available from: https://www.rki.de/EN/Content/Health_Monitoring/Health_Reporting/GBEDownloadsK/2011_6_fruit_vegetables.pdf?__blob=publicationFile [accessed Aug 1, 2024]

97. Dyrstad SM, Hansen BH, Holme IM, Anderssen SA. Comparison of Self-reported versus Accelerometer-Measured Physical Activity. Medicine & Science in Sports & Exercise 2014 Jan;46(1):99–106. doi: 10.1249/MSS.0b013e3182a0595f

98. Edwards JR, Bagozzi RP. On the nature and direction of relationships between constructs and measures. Psychological Methods US: American Psychological Association; 2000;5(2):155–174. doi: 10.1037/1082-989X.5.2.155

99. Breaks in Sedentary Time | Diabetes Care | American Diabetes Association. Available from: https://diabetesjournals.org/care/article/31/4/661/25574/Breaks-in-Sedentary-TimeBeneficial-associations [accessed Aug 5, 2024]

100. Unger JB, Johnson CA, Marks G. Functional decline in the elderly: Evidence for direct and stress-buffering protective effects of social interactions and physical activity1,2. Annals of Behavioral Medicine 1997 Jun 1;19(2):152–160. doi: 10.1007/BF02883332

101. Davis AJ, MacCarron P, Cohen E. Social reward and support effects on exercise experiences and performance: Evidence from parkrun. PLoS One 2021 Sep 15;16(9):e0256546. PMID:34525097

102. Effectiveness of Smartphone-Based Physical Activity Interventions on Individuals' Health Outcomes: A Systematic Review - Emberson - 2021 - BioMed Research International - Wiley Online Library. Available from: https://onlinelibrary.wiley.com/doi/10.1155/2021/6296896 [accessed Aug 1, 2024]

103. Zhang M, Wang W, Li M, Sheng H, Zhai Y. Efficacy of Mobile Health Applications to Improve Physical Activity and Sedentary Behavior: A Systematic Review and Meta-Analysis for Physically Inactive Individuals. International Journal of Environmental Research and Public Health Multidisciplinary Digital Publishing Institute; 2022 Jan;19(8):4905. doi: 10.3390/ijerph19084905

104. Chai LK, Farletti R, Fathi L, Littlewood R. A Rapid Review of the Impact of Family-Based Digital Interventions for Obesity Prevention and Treatment on Obesity-Related Outcomes in Primary School-Aged Children. Nutrients 2022 Nov 15;14(22):4837. PMID:36432522

105. Johansson L, Hagman E, Danielsson P. A novel interactive mobile health support system for pediatric obesity treatment: a randomized controlled feasibility trial. BMC Pediatrics 2020 Sep 23;20(1):447. doi: 10.1186/s12887-020-02338-9

106. Effectiveness of a novel digital application to promote fundamental movement skills in 3- to 6-year-old children: A randomized controlled trial: Journal of Sports Sciences: Vol 39 , No 4 - Get Access. Available from: https://www.tandfonline.com/doi/full/10.1080/02640414.2020.1826657 [accessed Aug 1, 2024]

107. Rodríguez-González P, Hassan MA, Gao Z. Effects of Family-Based Interventions Using Mobile Apps on Youth's Physical Activity: A Systematic Review. J Clin Med 2022 Aug 17;11(16):4798. PMID:36013037

108. de Wit JBF, Stok FM, Smolenski DJ, de Ridder DDT, de Vet E, Gaspar T, Johnson F, Nureeva L, Luszczynska A. Food culture in the home environment: family meal practices and values can support healthy eating and self-regulation in young people in four European countries. Appl Psychol Health Well Being 2015 Mar;7(1):22–40. PMID:25346476

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

109. Locke EA, Latham GP. The Application of Goal Setting to Sports. Journal of Sport and Exercise Psychology Human Kinetics, Inc.; 1985 Sep 1;7(3):205–222. doi: 10.1123/jsp.7.3.205

110. Latham GP, Locke EA. New Developments in and Directions for Goal-Setting Research. European Psychologist 2007 Jan;12(4):290–300. doi: 10.1027/1016-9040.12.4.290

111. Wunsch K, Nigg CR, Weyland S, Jekauc D, Niessner C, Burchartz A, Schmidt S, Meyrose A-K, Manz K, Baumgarten F, Woll A. The relationship of self-reported and device-based measures of physical activity and health-related quality of life in adolescents. Health and Quality of Life Outcomes 2021 Mar 1;19(1):67. doi: 10.1186/s12955-021-01682-3

112. Hjartåker A, Lund E. Relationship between dietary habits, age, lifestyle, and socio-economic status among adult Norwegian women. The Norwegian Women and Cancer Study. Eur J Clin Nutr 1998 Aug;52(8):565–572. PMID:9725656

113. Javaras KN, Rickert ME, Thornton LM, Peat CM, Baker JH, Birgegård A, Norring C, Landén M, Almqvist C, Larsson H, Lichtenstein P, Bulik CM, D'Onofrio BM. Paternal age at childbirth and eating disorders in offspring. Psychol Med 2017 Feb;47(3):576–584. PMID:27808013

114. Rabenberg M, Mensink GBM. Fruit and vegetable consumption today. GBE kompakt 2011;2(6). Available from: https://www.rki.de/EN/Content/Health_Monitoring/Health_Reporting/GBEDownloadsK/2011_6_fruit_vegetables.pdf?__blob=publicationFile [accessed Aug 2, 2024]

115. Pocock SJ, Assmann SE, Enos LE, Kasten LE. Subgroup analysis, covariate adjustment and baseline comparisons in clinical trial reporting: current practice and problems. Stat Med 2002 Oct 15;21(19):2917–2930. PMID:12325108

116. Ziesemer K, König LM, Boushey CJ, Villinger K, Wahl DR, Butscher S, Müller J, Reiterer H, Schupp HT, Renner B. Occurrence of and Reasons for "Missing Events" in Mobile Dietary Assessments: Results From Three Event-Based Ecological Momentary Assessment Studies. JMIR mHealth and uHealth 2020 Oct 14;8(10):e15430. doi: 10.2196/15430

117. Prochaska JO, Velicer WF. The Transtheoretical Model of Health Behavior Change. Am J Health Promot SAGE Publications Inc; 1997 Sep 1;12(1):38–48. doi: 10.4278/0890-1171-12.1.38

118. Garde A, Umedaly A, Abulnaga SM, Robertson L, Junker A, Chanoine JP, Ansermino JM, Dumont GA. Assessment of a Mobile Game ("MobileKids Monster Manor") to Promote Physical Activity Among Children. Games Health J 2015 Apr;4(2):149–158. PMID:26181809

119. Sirriyeh R, Lawton R, Ward J. Physical activity and adolescents: An exploratory randomized controlled trial investigating the influence of affective and instrumental text messages. British Journal of Health Psychology 2010;15(4):825–840. doi: 10.1348/135910710X486889

120. Fukuoka Y, Vittinghoff E, Jong SS, Haskell W. Innovation to Motivation - Pilot study of a mobile phone intervention to increase physical activity among sedentary women. Prev Med 2010;51(3–4):287–289. PMID:20600263

121. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, Goldfield G, Gorber SC. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity 2011 Sep 21;8(1):98. doi: 10.1186/1479-5868-8-98

122. Nigg C, Oriwol D, Wunsch K, Burchartz A, Kolb S, Worth A, Woll A, Niessner C. Population density predicts youth's physical activity changes during Covid-19 – Results from the MoMo study. Health & Place 2021 Jul 1;70:102619. doi: 10.1016/j.healthplace.2021.102619

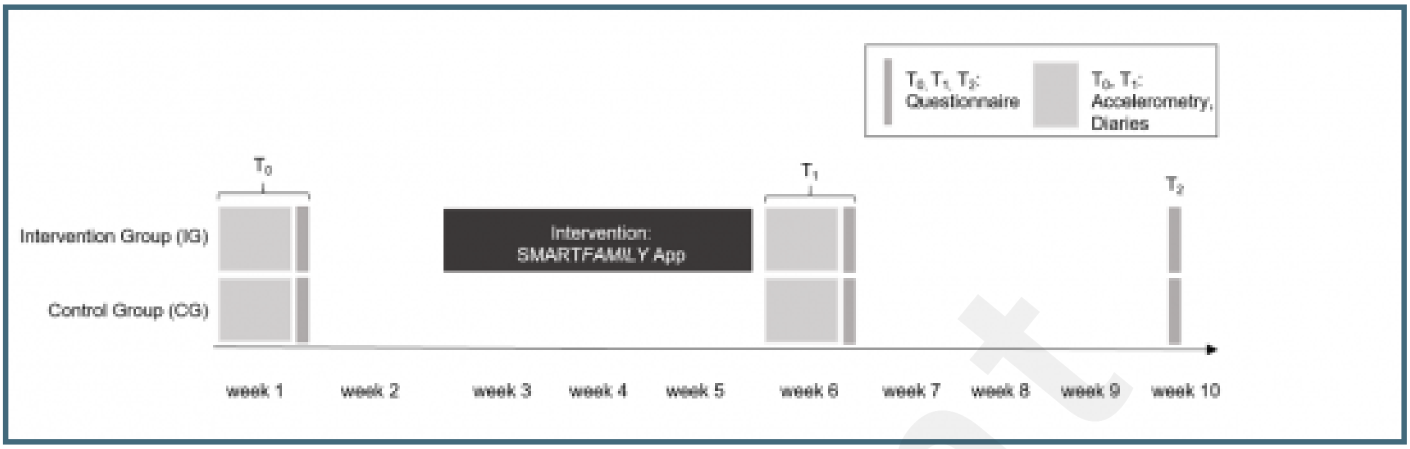
123. Wunsch K, Kienberger K, Niessner C. Changes in Physical Activity Patterns Due to the Covid-19 Pandemic: A Systematic Review and Meta-Analysis. IJERPH 2022 Feb 16;19(4):2250. doi: 10.3390/ijerph19042250

SMART*FAMILY:* family-based mHealth intervention for physical activity and healthy eating

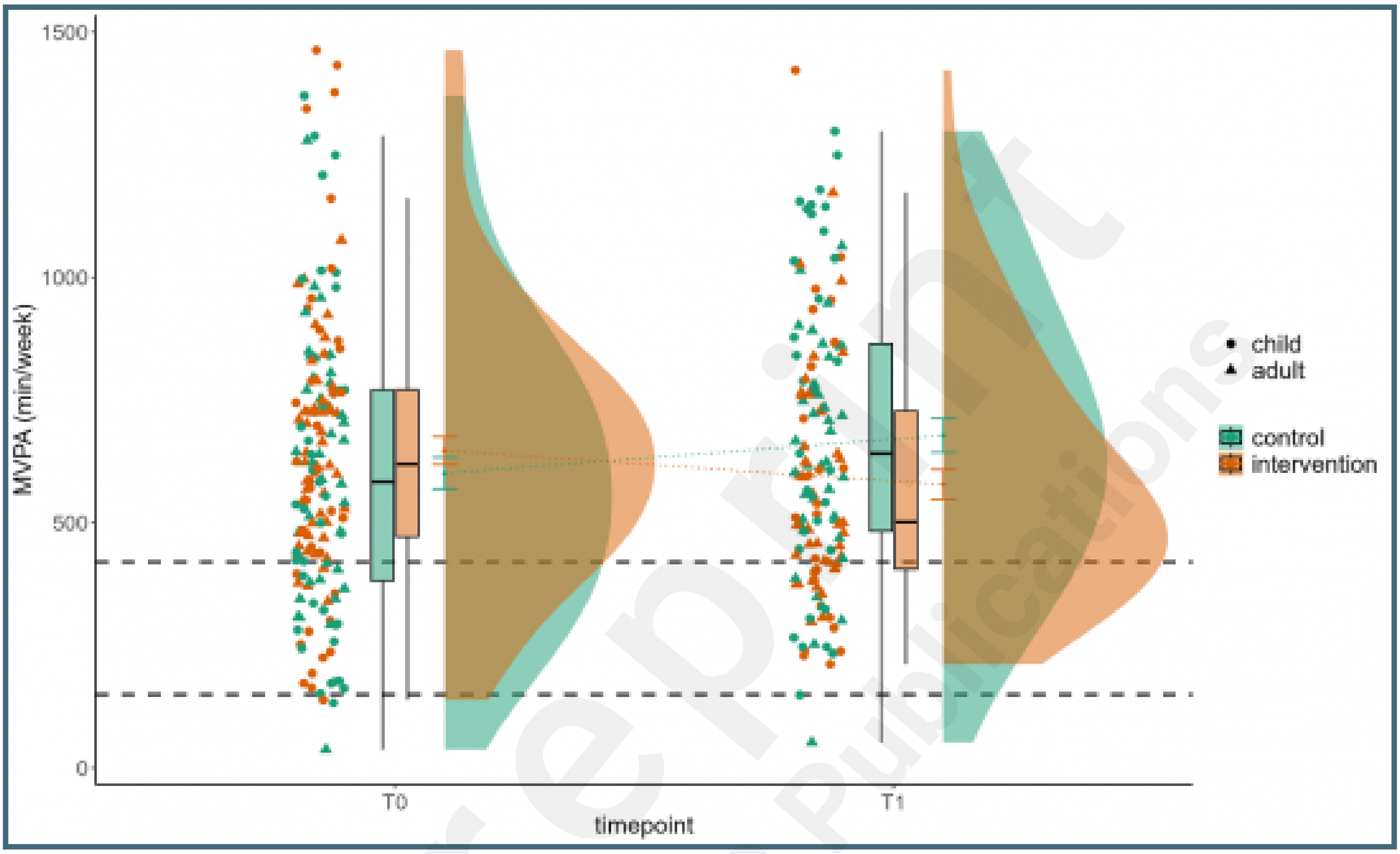
Supplementary Files

Figures

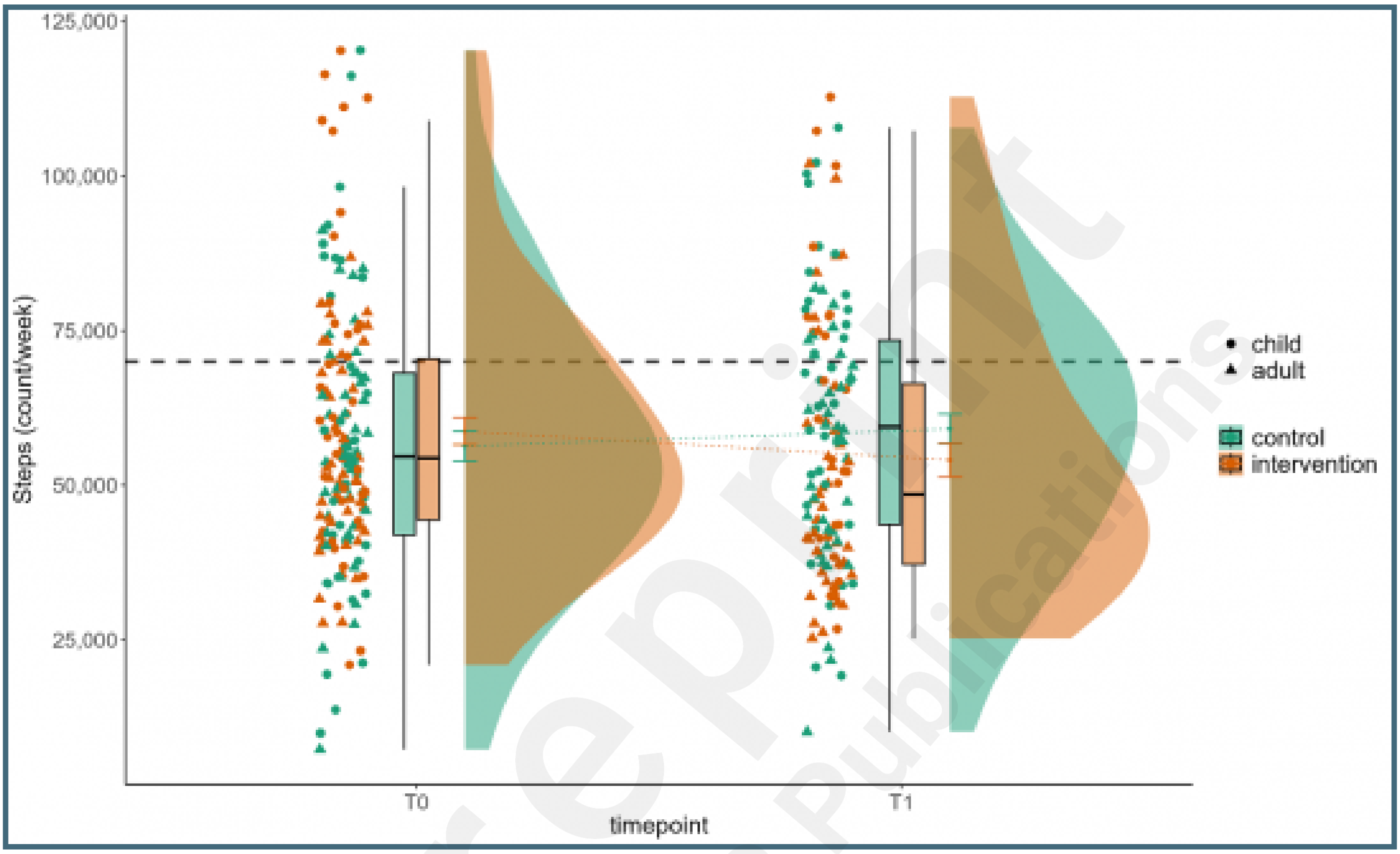
Detailed study design.



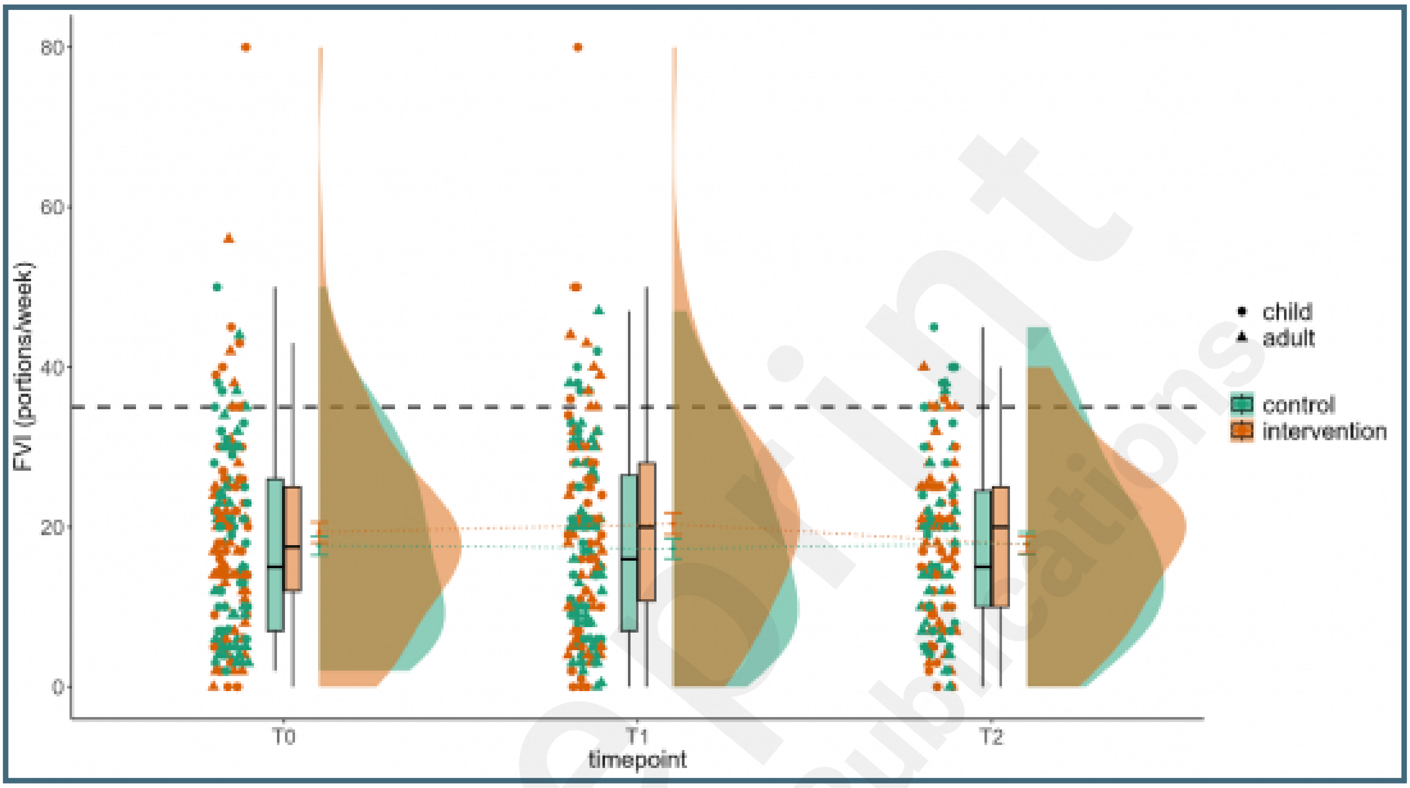
Interaction effect of group x time for device-based measured physical activity for the parameter minutes of moderate to vigorous physical activity per week (MVPA). Displayed is the mean MVPA (y-axis) of 180 participants during one week of baseline measurement (T0) and one week of post-measurement after a 3-week intervention/waiting period (T1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed lines represent the PA recommendations for children (420 min/week) and adults (150 min/week).



Interaction effect of group x time for device-based measured physical activity for the parameter steps per week (steps). Displayed is the mean step count (y-axis) of 180 participants during one week of baseline measurement (T0) and one week of post-measurement after a 3-week intervention/waiting period (T1) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the commonly used step recommendation of 10.000 steps/day (70.000 steps/week).



Interaction effect of group x time for the parameter fruit and vegetable intake per week (FVI) assessed by questionnaire. Displayed is the mean fruit and vegetable intake (y-axis) of 197 participants related to the week of baseline measurement (T0), the week of post-measurement after a 3-week intervention/waiting period (T1), and the week of follow-up measurement (T2) for the control group (green) and the intervention group (red), stratified by children and adults. The grey dashed line represent the recommendation for daily FVI of 5 portions (35 portions/week).



Multimedia Appendixes

Results of the main analyses.
URL: http://asset.jmir.pub/assets/b1a61d76349f3278e8e913f58a6af74c.pdf

Results of the sensitivity analyses.
URL: http://asset.jmir.pub/assets/f12352d24a014bcdb91f1e2f28991d41.pdf

CONSORT (or other) checklists

Appendix A. Consort eHealth checklist.
URL: http://asset.jmir.pub/assets/5690a0fb390ca2dd357035534152fbfb.pdf

TOC/Feature image for homepages

SmartFamily.