

VU Research Portal

Active video games: Can they contribute to the prevention of excessive weight gain in gaming adolescents?

Simons, M.

2015

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Simons, M. (2015). *Active video games: Can they contribute to the prevention of excessive weight gain in gaming adolescents?* [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

CHAPTER 8

General discussion



Aims

The overall aim of this thesis was to examine whether providing active games in a home setting can contribute to the prevention of unnecessary weight gain in gaming adolescents. The first part of this thesis focuses on analyzing the gaming behavior of adolescents by evaluating, the amount of time spend on active and non-active gaming and demographic variables associated with gaming. Further, it was explored how time spend in active gaming was associated with other energy balance-related behaviors. The second part evaluated the determinants of active and non-active gaming. Finally, in part 3 a randomized controlled trial was conducted among gaming adolescents who were mainly of healthy body weight to evaluate the effects of providing active games in their homes.

In this chapter the main findings will be summarized and critically evaluated. In addition, methodological considerations will be discussed. Next, the findings will be placed in a broader perspective analyzing if and how games can contribute to promoting health related behaviors in order to prevent overweight. This will lead to recommendations for practice and future research.

Main findings

In part 1, *Analysis of gaming behavior*, the survey showed (chapter 2) that the large majority of Dutch adolescents (83%) play video games, either active or non-active versions. Almost half of the respondents reported to play active games, especially those attending lower educational school levels, and most of them played active games in combination with non-active games. Sex and age were not associated with active gaming (≥ 1 h/wk) in adolescents, while findings showed that boys and older adolescents were more likely to play non-active games (> 7 h/week) than girls and younger adolescents. The amount of time spend on active gaming was relatively low compared to that spend on non-active games: 36 min on a school day and 42 min on a weekend day for active gaming versus 65 min on a school day and 80 min on a weekend day for non-active gaming. Importantly, chapter 3 (24-hours-recall study) showed that playing active games is unlikely to be a substitute of (other) physical activities. Yet, spending more time playing active games was associated with a small, but statistically significant longer TV/DVD time and intake of snacks. Another interesting finding from chapter 3 was that adolescents, who reported to have played active games, reported longer non-active game time than those who reported not to have played active games.

In part 2, *Analysis of determinants of engaging in gaming behaviors*, the findings of the focus groups in adolescents are presented (chapter 4). Adolescents indicated they liked active games; nonetheless a substantial proportion of them preferred non-active games. They mentioned, for example, that active games were of inferior quality compared to

non-active games in terms of graphics, accuracy, functioning of controllers, and variety. Furthermore, adolescents mentioned they liked playing active games when friends or family were visiting them and they liked laughing at each other while playing the active games. Besides that, they liked the interactivity of the active games, i.e., controlling the game with their body movements. The survey described in chapter 5 showed that various personal, social and game-related factors were statistically significantly associated with active gaming ≥ 1 h/wk and that these factors were partly different than those for non-active gaming > 7 h/wk. Regarding personal factors, a more negative attitude towards non-active games and a more positive attitude towards active games were associated with an increased likelihood of playing active games ≥ 1 h/wk. In addition, for non-active gaming, a more positive attitude towards non-active gaming and a more positive image of a non-active gamer were associated with non-active gaming > 7 h/wk. Habit strength correlated with both active ≥ 1 h/wk and non-active gaming > 7 h/wk. Concerning social factors, having brothers/sisters and friends who spend more time on active gaming was associated with playing active games ≥ 1 h/wk. Also for non-active gaming, having friends (but not brothers and sisters) who spend more time on non-active gaming, but also a more positive image of a non-active gamer were associated with non-active gaming > 7 h/wk. Finally, concerning game-related factors we found that a lower score on game engagement was associated with playing active games ≥ 1 h/wk. We did not find any associations between game related factors and playing non-active games > 7 h/wk.

In part 3, *Intervention development and evaluation*, chapter 6 described the content of the active game intervention and the study design to evaluate the intervention. The randomized controlled trial, presented in chapter 7, indicated that providing gaming adolescents with an active game and simultaneously promoting its use was ineffective in preventing unnecessary weight gain and even had some effects on anthropometrics in the unintended direction (i.e. in favor of the control group). The intervention did result in lower self-reported non-active game time and total sedentary screen time. No effects of the intervention were found on self-reported physical activity and consumption of sugar-sweetened beverages and snacks. The process evaluation showed that despite the intervention aiming to enable and motivate adolescents to engage in active gaming at least one hour per week, only 14% of the participants in the intervention group managed to do so. Frequently mentioned reasons for not playing the active games were lack of time, preferring to play non-active games, and the active games being experienced as boring.

Reflections on main findings

Many adolescents already play active games, but for a relatively low amount of time

In line with previous studies [1-4] our findings confirmed the pervasiveness and large dose of non-active game play among adolescents. The added value of our study

is the additional focus on active gaming; we showed that almost half of the adolescents already played active games, mostly in combination with non-active games. Time spent on active games was about half the time spent on non-active games, which is comparable to other studies [5;6]. Two other studies showed slightly lower rates of adolescent youth playing active games. A Dutch report showed that 39% of adolescents (aged 12 through 14 years) play active games at least once a week [5]. Next, a Canadian study found that 24% in 14-19 year olds had played active games at least once [7]. Three reasons could be given for the higher number found in our study compared to the other studies. First, our data were collected more recently and the higher number might indicate that active games gained popularity more recently. Second, the higher number in our study might be due to methodological differences in study populations or measures to assess active gaming. Third, it might be due to difference in reference period in assessing active gaming.

In summary, our results show – in line with other available research – that although many adolescents play active games, many more play non-active games and they spent far less time in playing active games than in non-active games. Thus, active games are theoretically a useful intervention tool and potentially reaching non-active gamers, because apparently many adolescents (including non-active gamers) are interested in it. On the other hand, our findings suggest that active games need further development before being able to compete with non-active games.

Active games seem to attract a wide range of adolescents and especially those attending lower educational school levels

Specific groups appeared to be attracted to and engaged in non-active and active gaming. Adolescents attending lower educational school levels were more likely to play active games regularly than adolescents attending higher educational levels. This suggests that active gaming is especially a promising tool for the adolescents attending relative low levels of education, who have most to gain by becoming more physical active, being less sedentary and weighing less [8;9]. Lower educated people are also difficult to reach with traditional health promotion messages [10;11]. Furthermore, the present findings suggest that active games are suitable for targeting both boys and girls, because sex was not associated with active gaming, in line with another Dutch study that found no sex differences for active gaming either [6]. However, a Canadian study showed that adolescent girls (14-19 year old) were more likely to play active games than boys [7]. The inconsistent findings of these studies could be due to the difference in operationalization of active gaming (playing active games yes/no or playing active games $< / \geq 1$ hour/week), cultural differences (The Netherlands versus Canada) or differences in the participants' age range (12-16 versus 14-19 years old). For non-active gaming we found that boys were much more into playing than girls, which is a well-established finding in game literature [3;12;13]. Hence, boys seem the most relevant target group with active games, when the aim is to substitute non-active game time. On the other hand studies suggest that girls are equally (chapter 2) or even more interested in active game play [7].

Moreover, the lower levels of physical activity in girls compared to boys [14] and the barriers girls experience for sports participation [15], illustrate the importance for new activity promoting tools (such as active games) to reach girls.

With respect to age, although one past study in Dutch adolescents found that regular active gamers were slightly younger than non-regular active gamers [6], in the present studies we did not find support for this notion. Yet, there are indications that younger children are more interested in active gaming than adolescents in general [5;16]. In accordance with this focus group findings also suggest that active games are more suitable for younger children than for adolescents [17;18]. Dutch 8-12 year olds mainly reported to prefer active games to non-active games [17], while Dutch 12-16 year olds mainly preferred non-active games to active games (chapter 4). Moreover, active games were perceived as more appropriate for younger children than teenagers according to 10-14 year old New Zealand children [18].

Though more research is necessary, based on our studies active games seem especially suitable for reaching adolescents attending a lower level of education, and at least equally suitable for girls and boys. Other studies suggest active games might be more appropriate for younger children than for adolescents.

Mixed evidence on associations between active gaming and other energy-balance-related behaviors

Sedentary behavior and physical activity

Active gaming may only be beneficial for energy balance when it replaces sedentary activities such as non-active gaming or TV viewing. We found that adolescents interested in active gaming were generally also more interested in non-active gaming. This was similar to the finding of O’loughlin and colleagues who found that active gamers were more likely to play non-active games than adolescents who did not play active games [7]. This suggests that an interest in active and non-active gaming is associated, which is desirable when aiming to replace non-active game time by active game time. However, actual time spent in active gaming and non-active gaming was not correlated (chapter 3). This suggests that when adolescents spend more time on active gaming it may not result in less non-active game time. Moreover, we found a small- but significant- association between active game time and TV/DVD time, which concurs with the finding of O’Loughlin that active gamers were more likely to watch more than 2 hours of television per day than adolescents who did not play active games [7]. Thus promoting active gaming could also result in more sedentary time. On the other hand, it may particularly attract adolescents who are already heavily engaged in screen activities. Causal inferences of these results should of course be made with caution, since these were cross-sectional associations. Three experimental and longitudinal trials have been conducted on this topic and show mixed evidence [Chapter 7]; 19;20]. In our trial (chapter 7) we found that providing active games including an encouragement to

replace non-active games with active games, decreased self-reported non-active game time and total sedentary screen time compared to a control group. However, in an earlier study no change was found in self-reported non-active game time after providing active games [19]. Important to highlight is that in both these trials non-active game time was self-reported and the intervention groups were explicitly encouraged to play the active games, potentially influencing their self-report. The only trial that measured behavior objectively was a cross-over trial showing that replacing non-active games with active games decreased total sedentary time in the after-school period but not across the whole week [20].

Another important energy-balance-related behavior is physical activity. Concerns have been expressed that adolescents may play active video games instead of other more traditional physical activities such as playing outdoors or sports. Playing outdoors and practicing outdoor sports activities offers the benefits of being outside such as fresh air, exposure to sunlight (vitamin D), connection with nature and social interactions and in general it requires higher energy expenditure than active gaming [21;22]. Three cross-sectional studies that aimed to shine more light on this possible compensation issue show mixed results [6;7;23]. Two out of three studies found no difference in physical activity between adolescents who did and who did not play active games (or less than 1 hour per week) [6;7]. Yet, a more recent study in young adults found that female active gamers reported more (47 minutes) physical activity in the past week than females who did not play active games [23]. It is not clear if these extra 47 minutes reflected active gaming itself or other physical activities. The study also showed that female active gamers were more likely to believe active games were a good way to integrate physical activity into their lives than male active gamers (89% vs. 62%). Therefore, it might be that females were more likely to include active gaming when answering physical activity questions than males. There is initial evidence to support this idea, as another study suggested that adolescent girls who play active games partially internalized active gaming as a physical activity behavior while boys may not view active gaming as physical activity [24]. Besides these cross-sectional studies, three longitudinal experimental trials have been conducted. Two of them did not find effects of providing and promoting active games on self-reported (Chapter 7) and objectively measured [19] physical activity. One cross-over trial though did find that replacing non-active games with active games increased objectively measured physical activity, but only in the after-school period and not across the whole week [20].

In sum, it is not clear yet how active gaming influences other physical activities and sedentary activities and thus the energy-balance. More longitudinal and experimental research including objective measures of physical activity and sedentary time is needed to shed more light on such compensatory behaviors.

Energy intake

Eating and drinking are also important energy-balance-related behaviors. In the 24-hours recall study we found that active game time was weakly associated with higher snack intake (chapter 3), while our trial provided no evidence that providing active games influenced consumption of sugar-sweetened beverages or snacks (chapter 7). Also an earlier study by Maddison et al., [19] in which participation in active games was higher than in our trial, found no effects of an active game intervention on snack intake either [19]. In all these studies dietary intake was self-reported and thus potentially influenced by social desirability or recall bias. De Groot et al., [25] evaluated objectively measured consumption of potato chips and coke during different screen activities in young adult Dutch males and showed that energy intake during active gaming was not different than during non-active gaming and watching TV. These results are in line with two other laboratory studies that evaluated energy intake during active and non-active gaming in young adults [26] and in children [27]. While in the studies of De Groot et al. [25] and Mellecker et al. [27] only energy intake was measured, Lyons et al., [26] additionally measured energy expenditure. Despite the equal energy intake during different activities, differences in energy expenditure in favor of active gaming were found [26]. Although the resulting lower energy surplus may make active gaming a healthier alternative to non-active gaming and watching TV, also active gaming resulted in a positive energy balance where caloric intake from foods and beverages exceeds the amount of calories expended during the activity [26]. Important to note it that all these studies [25-27] assessed energy intake during the activity only, but not afterwards. Adolescents consume more during an ad libitum lunch (10 minutes later) irrespective of hunger and appetite after playing non-active games for one hour than after resting in a relaxing sitting position [28]. It would be valuable to examine this potential compensation effect afterwards for active gaming and to evaluate whether these possible compensation effects differ between active gaming and non-active gaming.

In summary, it can be concluded that there is no clear evidence that active gaming leads to higher energy intakes during game time. However, it may be that after the gaming activity, energy intake may be higher. A longitudinal experimental study using valid measures of energy intake would be useful to get more insight in these potential unanticipated effects of promoting active gaming.

Adolescents seem to appreciate non-active games over active games

Our focus groups revealed that adolescents generally like active games, but preferred non-active games. Adolescents thought that active games were more boring, graphics and story line were less sophisticated, had more malfunction in technology and controllers, and had less variety in games compared to non-active games (chapter 4). For an active game intervention it seems therefore important to provide a wide range of active games and refresh the games often to keep adolescents interested. Aspects that adolescents did like about active games were merely related to physical activity and the

interactive aspect in the active game. Further, active games were considered more social than non-active games, as confirmed by previous studies that found that group play can encourage participation in active games [29;30]. Hence, the social nature of active games seems an aspect that could be used to motivate adolescents towards active games. Our findings that adolescents had a positive attitude towards both active and non-active gaming (chapter 5) and the suggested common interest of adolescents in both active and non-active gaming (chapter 3) seemed promising. However, adolescents preferred non-active games over active games (chapter 4), which indicates it may be challenging to motivate non-active gaming adolescents to replace non-active gaming with active gaming. Our finding that a more positive attitude towards non-active games was associated with a lower likelihood to play active games (chapter 5) substantiates this.

In summary, active gaming may be a way to encourage physical activity as adolescents do appreciate active games, but competition with non-active gaming seems tough.

Correlates of active gaming and non-active gaming are partly different

We found various personal, social and game-related correlates of active gaming and these were partly different from correlates of non-active gaming. More than non-active gaming, active gaming seems to be influenced by gaming behavior of brothers and sisters. Consistent with previous studies [Chapter 4; 29;30], our findings indicated that active gaming is more likely if siblings, and to a lesser extent friends, also play them regularly. Hence, to promote active gaming it seems wise to focus on multi-player games instead of individual play. Consequently, for our trial we decided to promote multiplayer play and to provide an extra game controller as part of the active game intervention. Further, we found no association between attitude towards physical activity and active game play, thus no support for the concern that only youth who like physical activity and are already physically active (and therefore not the main target group for physical activity promotion interventions) play active games. Habit strength was a correlate of both active and non-active gaming, indicating that both types of gaming may be habitual behaviors. It is important to know the extent to which gaming is a habitual behavior (more unconscious) or a planned behavior (more conscious), as changing both types of behavior request different intervention strategies. Habits are learned responses to cues in the environment that have become automatized. Such automatic behaviors, like habits, are often difficult to change [31] and require breaking existing mental associations between cues and gaming, while building new ones. For example placing the active game console in a highly visible and accessible place could serve as a cue for playing. This was also mentioned in the focus groups (chapter 4). In addition, we found that active game play was associated with lower engagement experience during game play. However, we do not know if it refers to a trait in the sense that some adolescents become more easily immersed when gaming or a state in the sense that some games have stronger immersive qualities (or a mix). Again, these findings should be interpreted with caution, since these were all cross-sectional associations, and thus no conclusions can be drawn about

causality. All in all, the correlates of active and non-active gaming provided input for further research into correlates and provided input for the development of the active game intervention.

An active game promotion intervention did not contribute to the prevention of unnecessary weight gain in adolescents

We found no evidence that providing active games and promoting its use, did contribute to preventing unnecessary weight gain among gaming adolescents. Only adolescents who played non-active games for at least two hours per week were included in our trial and there was no inclusion criterion based on weight status. As a result we mainly included adolescents with a healthy body weight, which may have minimized the ability to see significant differences in changes in anthropometric measurements. Indeed, the intervention group remained relatively stable regarding most anthropometrics over ten months and the majority remained having a healthy weight for the duration of the intervention. In the control group anthropometrics decreased somewhat, resulting in a significant difference between the control group and intervention group in favor of the control group. A possible explanation may be an increase in the consumption of snacks and sugar-sweetened beverages or a decrease in other physical activities in the intervention group. However, we consider this explanation unlikely, as the intervention did not significantly affect these behaviors.

The intervention did not succeed in enabling and motivating the adolescents to play the active games for a substantial amount of time; only 14% of the participants in the intervention group managed to play at least one hour per week throughout the 10-month intervention period. The process evaluation confirmed the findings of the survey and focus groups that adolescents think active games are boring and prefer non-active games. Currently available active games may not be appealing enough to adolescents and cannot yet compete with non-active games. In contrast, other studies did find beneficial effects of active gaming on anthropometrics [19;32;33]. However, these studies focused on treatment of overweight and obesity instead of prevention of unnecessary weight gain as in our study. Further, they gave a stricter instruction to use the active games [19;34] or embedded the active games in a structured or multicomponent program [32;33]. Nevertheless, we found less self-reported non-active game time (-1.8 hour/week) and a 0.8 times lower geometric mean of sedentary screen time in the intervention group compared to the control group, suggesting that the intervention did succeed in targeting underlying behaviors of overweight. However, these behaviors were self-reported.

In summary, we did not succeed in stimulating non-active gaming adolescents to play active games a substantial amount of time instead of non-active games in a 'free-play setting'. We found no indication that providing active games in a home setting contributes to prevention of unnecessary weight gain. Other studies suggest that active

games might be more successful as part of a treatment program for overweight and obesity, embedded in a broader program or with more prescription for usage instead of a stand-alone prevention tool and relying on spontaneous use.

Methodological reflections

The specific methodological issues regarding the separate studies are discussed in the previous chapters describing these studies. This section will discuss some general methodological considerations of the overall project.

Conducting research in adolescents

This thesis focuses on adolescents aged 12 – 17 years old and the findings of this thesis cannot be generalized to other age groups. The rationale to focus on adolescents, as explained in more detail in the introduction, was the high prevalence of unhealthy overweight-related behaviors [8], and the fact that weight status and life style behaviors during this life stage often track into adulthood [35]. However, conducting research in adolescents involves some specific challenges in terms of recruitment and retention, consent and confidentiality and the additional role of parents [36]. Even though it seems easy to reach adolescents through schools, recruitment is often difficult because of strict rules regarding consent and because many adolescents have other interests than participating in research [36]. Studies involving more interactive and digital tools (such as internet, texting, and games) seem to be more appealing to adolescents [36].

Besides recruitment, also data collection can be challenging in adolescents; during our data collection we experienced once that an adolescent was not filling in the questionnaire seriously but was making up answers on purpose, so we excluded the questionnaire for the analysis. However, often researchers are not present when the adolescents complete questionnaires, making it hard to judge whether answers are valid or not. Adolescents might click through or skip questions to be finished quickly and only participate for the incentive. Therefore, we made the questionnaires as user-friendly as possible by using a structured online tool, or arranged that adolescents could complete the questionnaire during school time so not at the expense of their leisure time. Also in qualitative data collection one should be aware of adolescence-specific challenges. We conducted focus groups with adolescents to evaluate their views on active and non-active games. Possibly the adolescents were influenced by the presence of the researcher and other adolescents, as adolescent life stage is characterized by increasing peer influence [37]. Parents and teachers were not allowed to be present during the focus groups, to prevent that adolescents would not feel comfortable to speak freely. Further, we tried to create an open and relaxed atmosphere in which all participating adolescents felt comfortable and we gave everybody the opportunity to speak. Despite these efforts, it still could be that some adolescents said things under the influence of peer-pressure or were afraid to contradict their peers.

Objective measures could overcome these problems, but are not always available or face too many practical issues. We used objective measures for proxy measures of adiposity (BMI, skinfolds, hip and waist circumference). However, a potential problem with these anthropometric measures in adolescents is that they change considerably over time with large individual differences because of differences in onset of puberty. Puberty concurs with hormonal changes, which can cause a rapid increase in height and changes in amount and location of body fat [36-38]. Consequently, pubertal stage could be a confounder and preferably should be adjusted for in the analyses. We decided not to do this because the assessment of pubertal status is sensitive and intrusive for adolescents [36]. Further, because we randomized participants in our trial we assumed that puberty status is evenly distributed in both the control group and intervention group and probably did not influence the results.

Recruitment

We used schools as a main source for recruiting adolescents, as this is the most convenient place to recruit adolescents. We succeeded to include a representative group of adolescents in the survey in terms of age, sex, ethnicity and educational level [Chapter 2; 39], which is important in order to get a valid estimation of prevalence of active and non-active gaming of adolescents in The Netherlands. The 24 hours-recall diary investigated among active gamers how active gaming is associated with other behaviors. Hereto, we needed adolescents who played active games and so we collaborated with a panel agency that had access to a large group of adolescents who met that criterion. Hence, the study population was not representative for a general group of adolescents, as not all adolescents play active games. Finally, in the trial we used a wide variety of sources and it took a lot of effort to recruit the 270 participants; thousands of letters and flyers were spread at schools, advertisements were placed on game websites and newsletters et cetera. This probably means that a highly selective group of gaming participants was recruited in our trial, which may not be representative for gamers in general. We focused on PlayStation 3 gamers, because we found that many adolescents play games on this console. However, the findings may not be fully generalizable to other console gamers. Further, our participants consisted of a group of adolescents who spent a relatively high amount of time in playing non-active games, and comparing them to a general group of Dutch adolescents they could be called 'excessive' gamers. The intervention may be more effective among less 'excessive' non-active gamers since 'recreational' gamers might be easier to motivate to active gaming. It is worth noting though that the internal validity could be considered high, because of the extremely low drop out.

Study designs

Strong aspects of the studies in this thesis are the systematic approach and wide variety of study designs and research methods. We used focus groups to get more in-depth knowledge on the views of adolescents, which were further investigated quantitatively in a survey. To shed more light on how active gaming is associated with

other energy-balance-related behaviors, we conducted a diary study including multiple 24-hour recalls. In this study adolescents filled in their activities for 7 days randomly spread over one month. Because we assessed 7 random unannounced days instead of a single point in time, we maximized the chance to capture a true representation of normal daily behavior. Finally, to evaluate the effects of an active game intervention we used the ‘gold standard’ in scientific evidence, i.e. a randomized controlled trial.

Some limitations should be mentioned in the study designs we used. Although focus groups are very suitable for gaining in-depth knowledge about a relatively new subject, a limitation is that the findings are not generalizable. Therefore, we additionally investigated the findings quantitatively in a survey. In turn, a limitation of the survey was the cross-sectional design, which precluded conclusions about causality. However, we did not aim to examine causality, but to explore associations to inform the active game intervention development. This causality inference problem also applies for the 24-hours-recall study. Lastly, also some limitations apply to the randomized controlled trial. The participants, researchers and research assistants were not blinded, as this was complicated because of the nature of the intervention and for logistic reasons. Consequently, the control group knew that they were the control group and that the intervention consisted of receiving an active game application including active games. This could have resulted in contamination. However, the process evaluation and self-reported game behavior findings do not confirm this concern. An alternative design that can be considered in future active game studies is a randomized controlled trial nested within a cohort study (RCT nested in a cohort design). This design can overcome problems regarding recruitment and not being able to blind participants that are associated with regular randomized controlled designs [40]. Further, to prevent fading out interest in the active games, future studies might consider adjusting the intervention (e.g. changing the active games and/or implementation strategies) during the study period, i.e. an adaptive trial.

Data collection and measures

We used mixed methods to collect data: focus groups to collect qualitative data and questionnaires, a 24-hours-recall diary and anthropometric measures to gather quantitative data (self-reported and objective). Below we elaborate on some issues related to self-reported measures and measuring anthropometrics.

Measuring self-reported behavior

We mainly used self-reported (behavioral) measures as there are no appropriate objective measures available yet for the aspects we were interested in. A general limitation of self-reported measures is the liability to recall bias and social desirable answers.

Time spent playing active and non-active games was assessed using questions derived from existing and validated questionnaires, however we modified the questions to reflect

the target behavior gaming and the modified version was not validated. So we do not know to which extent the assessed gaming behavior reflects actual gaming behavior. The correlates of active and non-active gaming were also based on self-reported data and consequently the same limitations apply as mentioned above. We mainly used readily existing and valid instruments to measure potential correlates. However, to ensure an acceptable length of the questionnaire we had to shorten some of the scales, which might have influenced the validity of the included measures. To minimize possible negative influences on validity we removed the items with the lowest factor loading. In the 24-hours-recall diary study, we assessed adolescents' time spent in a wide range of activities conducted in the past 24 hours. We wanted to get a complete picture; hence we included many activities in the diary resulting in a very long questionnaire. The length of the questionnaire and the fact that it had to be completed seven times, could have resulted in less reliable answers. We used a structured online diary with programmed routings to make it as easy as possible to complete it, but this also made it easy to click through the questions very fast without reading or thinking about the answer. Again, this questionnaire was based on validated questionnaires, but modified (to target gaming behavior and make it suitable for the online tool) and the modified version was not validated. Further, we used text messages to improve response rates. In the trial, physical activity and sedentary behavior were again self-reported and these self-reports have limited validity [41;42]. To assess active game behavior the adolescents filled in a game calendar every day they played active games. To improve compliance we made the calendar attractive and easy to fill in. However, the validity of the game calendar is unknown.

An alternative to self-report measures for assessing physical activity and sedentary time is accelerometry. Accelerometers are a valid method to objectively measure physical activity and sedentary time and have been previously used in active game trials [19;20]. However, compliance to the accelerometers protocol is often poor and there are many potential practical problems (e.g. loss or damage) when using them in large-scale studies [43;44]. Moreover, it can be questioned whether accelerometers are sensitive enough to accurately detect physical activity elicited by active gaming. Many active games require mainly upper body movements that are difficult to detect by an accelerometer worn on the hip [45]. A solution might be to wear the accelerometers on the wrist [46]. Further, accelerometers do not provide information on the type of activity, and where and with whom activities are being performed. Nevertheless, objective measures are recommended in future active game studies, but preferably in combination with self-report. Furthermore, other objective measures should be explored, for instance data (on game time and activities) that are stored continuously in game consoles. Baranowski and colleagues tried to use the game play data recorded by the Wii console [47]. However, these data appeared not very reliable, as some time periods of playtime recorded by the console were excessive (e.g. 24 hours) suggesting that players left the console on without actual playing. Further, the console does not record who is playing the game: the child, a friend, sibling, parent, or others [47]. Other consoles also store game data but our experience learns that companies

are not always willing to provide them because of privacy issues. Despite these limitations and problems, console-recorded data seem of potentially high value for research purposes and it is recommended to further explore how this data can be retrieved and analyzed.

Measuring anthropometrics

A strong feature of the trial was that we objectively measured height, body weight, waist and hip circumference, and skinfold thickness. Height and weight were used to calculate BMI, which is considered a suitable and accepted proxy measure of adiposity [38]. However, as discussed earlier there are also some limitations and considerations regarding using BMI in adolescents. Whereas in adults the BMI cut points that define obesity and overweight are not linked to age and not dependent on sex, they are in growing adolescents. Hence, for BMI to be meaningful in adolescents it must be compared to a reference standard that takes into account age and sex [48]. Therefore we decided to use BMI-SDS as the primary outcome variable. As recommended we used an external reference (the population from 1997 described in Schönbeck et al., [9] instead of an internal one (sample-based) to calculate BMI-SDS [48]. However, there are discussions and disagreements about what the optimal BMI-related measure for evaluating change is [38]. For example, it has been suggested that crude BMI should be used as the analytic variable with adjustment for age and sex in the actual analyses [38]. Yet, by using such an internal reference standard (sample-based) for age and sex, the interpretability of the findings decreases [48]. Alternative to BMI are direct measures of body fat such as dual-energy radiograph absorptiometry [43]. However, these direct measures are expensive and time consuming, and were therefore not suitable for inclusion in the trial that we conducted.

Games for overweight prevention in a broader perspective

Video games are an integral and important part of adolescent's life [1;2;49;50]. It has even been suggested that a life without is impossible for adolescents [20;49]. Therefore, it makes sense to find ways to use game technology to achieve positive effects, such as promoting healthy behaviors, rather than try to ban it and only focus on potential negative effects such as sedentariness, aggressive behavior, increased level of hyperactivity, lower levels of prosocial behavior and life satisfaction [51] or neglect of school responsibilities [50]. As such, more and more initiatives arise that try to harness the broad appeal of video games for health promotion.

Games being used for another purpose than pure entertainment (e.g. to educate, train, or promote behavior change) are called 'serious games' [52]. Serious games are increasingly prevalent in a broad area of domains such as defense (military training), education, and health care [52;53]. Active games, where this thesis focused on, can also

be considered a form of serious games. Although the active games that we focused on were originally developed for entertainment reasons, they can also be used for other (serious) purposes such as physical activity promotion. The use of game strategies and techniques is not limited to consoles only, as we see a growing use of game elements in mobile phone apps [54]. This usage of game strategies and features in non-gaming contexts is called ‘gamification’ (55). Examples of game strategies (i.e. the motivational elements typical for game-design) are Challenge, Phantasy, Story line, Competition, and Exploration [56;57]. The use of game strategies in interventions is promising as it might make interventions more fun and appealing. Hence, incorporating the game strategies and game techniques that make entertainment games appealing and addictive (in a positive way) in behavior change programs, might contribute to overcome major setbacks associated with traditional programs such as low reach of the at risk groups (e.g. people with a low social economic status), motivational issues, low adherence [58].

Below it is discussed how game strategies and techniques can be used in digital devices for promoting healthy energy balance -related behaviors (e.g. diet, physical activity and sedentary behavior) in order to prevent overweight. Serious games played on consoles or personal computer, and serious games (apps) played on mobile phones are considered.

Serious games for overweight prevention played on consoles

Besides active games, also other forms of serious games for promoting healthy energy-balance-related behaviors are being developed. Escape from Diab and Nanoswarm are examples of serious games (played on a Mac computer) aiming to promote healthy energy-balance-related behaviors that incorporate both behavior change techniques (e.g. goal setting, modelling) and game elements (e.g. story line, exploration) [59]. These are action-adventure games comparable to the experience of commercial quality video games and incorporate behavior change techniques woven in and around the game story. The game Escape from Diab is about an athletic adolescent, DeeJay, who falls through a door while playing soccer with his friends. He awakens in a colorless land called Diab, which is ruled by King Etes who oppresses the people living in Diab by ‘forcing’ them to have unhealthy diets and to be physically inactive (story line). DeeJay tries to escape from Diab and King Etes with his friends by introducing them to healthy eating and sufficient physical activity as a way to gain the mental acuity and physical fitness needed to escape from Diab (exploration, modeling). During game play the player has to set goals regarding diet and physical activity (goal setting) [60]. A randomized controlled trial showed that playing Escape from Diab and Nanoswarm resulted in increased fruit and vegetable intake in children [59], making it a promising tool to contribute to the prevention of overweight. A limitation however of these and many other current available serious games, is that they do not require physical activity and are often played inside while seated behind a computer or TV screen. Promising developments are serious games that also require physical activity to play the game, such as ‘Alien Health’

[61]. In this serious game the player learns about healthy diet while engaging in short cardio exercises using Kinect (an active game) technology.

Emerging evidence suggests that serious games can be effective in changing health behavior or its determinants, although effectiveness varies between the serious games [58]. A meta-analysis showed that serious games benefit from a strong focus on gaming theories or foundation in both behavioral and gaming theories [58]. However, it is unclear which specific behavior change strategies, game strategies and game mechanics determine the effectiveness of a serious game for healthy lifestyle promotion. There is a lack of systematic descriptions of the game design and evaluations of developed serious games and there seems a need for a conceptual framework combining behavior change theories with game design theories to guide and evaluate serious games for healthy lifestyle promotion.

Serious games for overweight prevention played on mobile phones

Another promising digital device for promoting healthy behavior using game strategies and techniques are mobile phones. The enormous rise in mobile phone and smartphones use and technique has resulted in an exploded availability of apps and mobile games, including apps for healthy lifestyle such as promoting physical activity, and a healthy diet [62-65]. Apps offer the opportunity to provide tailored feedback and advice at the appropriate time and place and real-time and place assessment and feedback that are more likely to be effective for behavior change [62]. Moreover, these mobile games and apps can take players outside and overcome the downsides of sitting inside behind a computer [65]. Mobile phones are a very suitable device for gamification and health promotion, because of technologies such as GPS (Global Positioning System), built in accelerometers and external wearable sensors (e.g. measuring heart rate, blood pressure, blood sugar). To illustrate, GPS provides information on location, distance, time and speed, which can be used as part of game play that requires players to go outside and perform game tasks in specific areas in their neighborhood [65]. In this way game maps are existing streets in the real world and players are for example instructed to collect items or treasures or to avoid items/traps that are put somewhere on the game map (and thus also in the real world). In this way the 'real world' is combined with the 'virtual world' (also called augmented reality), and the 'real world' is being used as a 'game world'. A growing amount of mobile games and apps that incorporate GPS become available [65]. Examples of game types are geocaching (games virtual treasure hunting and visiting new locations), geodashing (competitive online game in which the entire world is the playing field and players receive a list of random locations (dashpoints) and they have to visit as many of these points as possible within a specific amount of time), geohashing (an adventurous journey to random places within a given area). A well-known and popular example of a physical activity promoting app using gamification and GPS is Zombies run, which has more than 800.000 players (<https://www.zombiesrungame.com/> [66]). This is a running app in which the player hears an adventurous story through his/her

headphones and receives assignment (e.g. collect things, warnings that the zombies are coming and he/she need to speed up) and when the player get back home he/she can use the collected items or achieved assignments to build their own base.

Incorporation of game features is prevalent in apps, but often limited to only a few game strategies and techniques [64]. Also the use of evidence based behavior change techniques is scarce, while this is important for apps to be effective tools for changing health behavior on the long term [62;63]. Unfortunately, little is known yet about the effects and sustained use of mobile apps (using game elements) for prevention of overweight. A review has suggested that mobile health interventions may be effective in adult weight management in the short term [67]. Also, pilot studies have reported that mobile apps can be a feasible tool for weight management [68;69]. However, most of these apps do not incorporate game strategies (or only a few). Collaboration between game designers, health professionals and behavior change experts is warranted to link game strategies and techniques to evidence based behavior change techniques and incorporate those in apps. Future research should identify which of these game strategies and behavior change techniques are most effective in changing behavior.

Active video games in a broader perspective

This thesis evaluated the potential of using active video games for overweight prevention in gaming adolescents in a home setting. We focused on the commercially off-the-shelf active games such as the Wii, Dance Dance Revolution, PlayStation Move, or Xbox Kinect. These games are developed for commercial reasons, to make profit, and not with the aim to promote physical activity although these games might be used to that end. Not all these active games elicit moderate intense physical activity, which is required to contribute to meeting the physical activity guideline (i.e. accumulate at least 60 minutes of moderate to vigorous physical activity per day). Next to these commercial off-the-shelf active games, there are also active games that are specifically developed to increase physical activity or decrease sedentary time [70;71]. These active games might be more suitable for physical activity promotion as some of these games seem to require more intense physical activity then for example the Wii [72]. Most off-the-shelf active games are mainly developed for in home use, although they also can be used in other settings, such as school, playgrounds, workplace or nursing home. Combining this setting might increase impact. Further, other target groups than adolescents can be considered. Below, these other settings and target groups are being discussed.

Active video games in a school setting

This thesis focused on active video games in the home setting, but several studies indicated schools might also provide valuable opportunities for active gaming [32;73-75]. Schools can be considered as an ideal setting to improve health behaviors in adolescents,

because of the wide reach in terms of socio-economic status and ethnic backgrounds [76]. Further, adolescents spend most of their time in school sitting so there is much to be gained with respect to reducing sedentariness. An example of combining active game technology with school lessons to decrease sedentariness is the 'Mobile Class' [71]. Further, active games might be used in physical education to enhance interest and competence [77-79]. So far most studies on active games in a school setting have small sample sizes [32] or are observational [73;75], so little is known about effectiveness. Further, studies showed that sustained use of active games is challenging in a school setting. We need more insight in how active games should be implemented in a school setting to achieve sufficient and sustainable use of active games. Further, we need randomized controlled (or nested cohort) trials to get more insight true effects on health behaviors and indicators of overweight.

Active video games in the outdoors

Game elements can also be used in outdoor play facilities. In this way the benefits of gaming (e.g. high appeal, motivation and fun) are combined with the benefits of being outside. Hence, it meets the preference of parents that their child plays outside [17]. Examples are the Swinxs and YalpSona that have been shown to elicit an energy expenditure between 7 and 10 METs and thus sufficient to contribute to meet the physical activity guideline [70;80]. As far as I know, no research has been done yet on the effects on physical activity behavior change on the long term.

Active video games in a work setting

There are also games that focus on improving employee's health and wellbeing [81;82]. Active games can for example be implemented at work to stimulate physical activity in employees and to interrupt sedentariness. Sedentary behavior is known to be associated with negative health outcomes in adults and for many people work is a main source of sedentary time [83]. Active games such as Lasersquash might be placed on the work floor to motivate people to interrupt their sedentary time and be active for a couple of minutes [82]. Playing Lasersquash can elicit moderate to intense physical activity in employees, however again sustainable sufficient participation is challenging [84].

Active video games for therapeutic use

Active video games seem also to be a promising tool for therapeutic purposes in rehabilitation and illness management: e.g. balance training in elderly, burn wounds therapy, rehabilitation among children with cerebral palsy, to combat cancer-related fatigue in hospital patients, physical activity promotion in hospitalized inpatients or long-term care residents, Parkinson disease therapy, recovering from stroke [85]. The benefit lies in that games may make exercise and therapy less boring and more fun or can provide distraction from pain or fatigues. A recent review showed that the majority of studies showed promising results, but that most studies were pilot trials and there were few randomized controlled trials [85].

Implications for future research and practice

Implications for future research

Most studies so far focused on energy expenditure showing that playing active games leads to light to moderate intense physical activity. Studying the effectiveness of active games for overweight prevention is relatively new and shows conflicting results; some studies found significant effects on physical activity, sedentary behavior and BMI while others did not. Therefore, more randomized controlled (or nested cohort) trials with longer follow-up are of high value to bring the field of active games further. However, the level of participation and continuation in active game play is often low. Therefore, the first step is to examine which factors can enhance participation in active game play. Simply providing an active game seems not enough to result in sufficient active game play and increase physical activity. Therefore it is important to learn more about the optimal circumstances, conditions and implementation strategies. Should the active games be embedded in a structured program for example at schools? Does integrating a competition or cooperation element contribute to increased active game time [86]? How can we achieve that active games hook people in the same way that non-active games do? Do we need new (better) active games? Are active games more promising in other target groups?

Up till now most studies focused on commercially available active games that were not primarily developed to promote physical activity. Consequently, these active games include little or no theory based behavioral change techniques [87]. As theory based interventions are more likely to be effective (88), it is recommended that researchers, game designers and adolescents collaborate in designing and evaluating theory based active games that are attractive to the target group. Future research is necessary to show whether these active games that are specifically designed for physical activity promotion and based on evidence based behavior change theories, are indeed more effective than the commercial active games. Therefore it is important to gain insight in which behavioral change techniques and game strategies are associated with effectiveness. The world of games and technology is developing rapidly and new technologies and applications arise fast. For health researchers to keep up with this rapid developing world and learn about the benefits and possibilities for health promotion, more cooperation with computer scientists, game designers and game industry is desirable. Further, as mentioned above, active games are only one form of how games can be used for health promotion. Future studies should also focus on other forms of serious games and other digital devices that use game features such as mobile games and their potential contribution to overweight prevention.

Implications for practice

Recommendations for game developers

Our study results indicate that there is need for a new generation of active games to be able to compete with non-active games. Straker et al. [89] indicated that for active

games to be sustained as popular non-active games, they may need to incorporate features that are more aligned to relevant principles that are used in non-active games. They also recommend multidisciplinary collaboration to further develop and apply a comprehensive set of principles for best practice of active games [89]. In addition, studies have shown that not all active games are truly active. Most Wii games for example only require low intensity physical activity and it is easy to compete with very little body movements (for example the tennis games can easily be played while sitting on the couch and only making small wrist movements). The PlayStation EyeToy games generally require only small arm movements similar as in the Wii games. Active games that require both upper and lower body movements, e.g. Dance Dance Revolution, generally require the highest energy expenditure [90]. Smart phones and new technologies such as GPS (as described above), wearable sensors, but also virtual reality glasses (e.g. Oculus) provide many opportunities to bring active games a step further.

Recommendations for parents and health professionals

We found no evidence that providing active games to adolescents is effective in contributing to the prevention of overweight in adolescents. So based on our study results we cannot recommend parents to buy active games instead of non-active games.

Main conclusions

Playing video games is an enormous popular activity and is still increasing in popularity. Inspired by the new development of active games, this thesis evaluated the potential of active video games as a novel overweight prevention tool for gaming adolescents. Based on this thesis, the following conclusions can be made:

- The majority of adolescents play video games and almost half play active video games, but time spent on playing active video games is much lower than on non-active video games.
- Both boys and girls play active video games, and especially adolescents attending lower educational school levels play active video games.
- Playing active video games is considered a social activity, as it is played often with friends and brothers and sisters. Further, having other people (brothers/sisters and friends) around you increases the likelihood of playing active games yourself.
- Gaming adolescents do not consider active video games as an attractive alternative for non-active video games. Together with the finding that habit strength is an important correlate of actual gaming behaviour, it may be hard to replace non-active game time with active game time.
- Playing active video games does not seem to replace other physical activities. We found preliminary indications that playing active video games can result in less sedentary time and non-active game time. The effects of playing active video games on energy intake are unclear yet.

- Providing and promoting active video games to adolescents who already play non-active video games does not result in a substantial active game play time and does not contribute to the prevention of overweight.

Future studies are necessary to evaluate which strategies can motivate non-active gaming adolescents to play active games for a substantial and sustainable amount of time instead of non-active video games or whether active video games might be more suitable for other target groups. All in all, for now, we do not recommend to provide active video games to gaming adolescents in their home with only a light encouragement to play them.

References

1. The Netherlands National Gamers Survey 2009. Available at: www.newzoo.com/press/TodaysGamers_SummaryReport_NL.pdf.
2. Nikken P. Computerspellen in het Gezin. Hilversum, The Netherlands. NICAM 2003 (in Dutch)
3. Rideout VJ, Foehr UG, Roberts DF. Generation M2 media in the lives of 8- to 18-years olds. Menlo Park, CA: Kaiser Family Foundation 2010.
4. Videogames in Europe: 2012 Consumer Study. European Summary Report November 2012. Ipsos MediaCT and The Interactive Software Federation of Europe (ISFE). Available at: http://www.isfe.eu/sites/isfe.eu/files/attachments/euro_summary_-_isfe_consumer_study.pdf.
5. Stuy M, Wisse E, van Mossle G, Lucassen J, van den Dool R. School, Bewegen en Sport: Onderzoek naar relaties tussen de school(omgeving) en het beweeg- en sportgedrag van leerlingen. W.J.H. Mulier Instituut. Arko Sports Media, Nieuwegein 2011.
6. Simons M, Bernaards C, Slinger J. Active gaming in Dutch adolescents: a descriptive study. *Int J Behav Nutr Phys Act* 2012, 9:118.
7. O'Loughlin EK, Dugas EN, Sabiston CM, et al. Prevalence and correlates of exergaming in youth. *Pediatrics* 2012, 130(5):806–814.
8. Brug J, van Stralen MM, Te Velde SJ, Chinapaw MJM, De Bourdeaudhuij I, Lien N, Bere E, Maskini V, Singh A, Maes L, Moreno L, Jan N, Kovacs E, Lobstein T, Manio Y. Differences in weight status and energy balance-related behaviors among school children across Europe: the ENERGY-Project. *PLoS One* 2012, 7(4):e34742.
9. Schönbeck Y, Talma H, van Dommelen P, Bakker B, Buitendijk SE, HiraSing RA, van Buuren S. Increase in prevalence of overweight in Dutch children and adolescents: a comparison of nationwide growth studies in 1980, 1997 and 2009. *PLoS One* 2011, 6(11):e27608.
10. Singhal A. Entertainment-education and social change – history, research and practice. Mahwah, NJ: Lawrence Erlbaum Associates, 2003.
11. Van den Berg M, Schoemaker CG. Effecten van preventie [Effectiveness of prevention]. Deelrapport van de VTV2010 van Gezond naar Beter. RIVM: Bilthoven, 2010.
12. Marshall SJ, Gorely T, Biddle AJH. A descriptive epidemiology of screen-based media use in youth: A review and critique. *Journal of Adolescence* 2006, 29 (3):333–349. doi: 10.1016/j.adolescence.2005.08.016
13. Roe K, Muijs D. Children and Computer Games: A Profile of the Heavy User. *European Journal of Communication* 1998, 13 (2): 181–200. doi: 10.1177/0267323198013002002
14. Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol.* 2011, 40(3):685–698. doi: 10.1093/ije/dyq272
15. Casper JM, Jason N, Bocarro, Michael A. Kanters, and Myron F. Floyd. “Just Let Me Play!”—Understanding Constraints That Limit Adolescent Sport Participation. *Journal of Physical Activity and Health* 2011, 8(Suppl 1), S32–S39

16. Wesselman M, Simons M, de Boer MR, de Vet E. Kinderen en games: Voorspellers van spelen en aanschaffen van (actieve) games. Rapport VU Amsterdam, 2010. (in Dutch)
17. De Vet E, Simons M, Wesselman M. Dutch children and parents' views on active and non-active video gaming. *Health Promot Int* 2014, 29(2):235-43. doi: 10.1093/heapro/das064. Epub 2012 Dec 2.
18. Dixon R, Maddison R, Ni Mhurchu C, Jull A, Meagher-Lundberg P, Widdowson D. Parents' and children's perceptions of active video games: a focus group study. *J Child Health Care* 2010, 14(2):189-199.
19. Maddison R, Foley L, Ni Mhurchu C, Jiang Y, Jull A, Prapavessis H, Hohepa M, Rodgers A. Effects of active video games on body composition: a randomized controlled trial. *Am J Clin Nutr* 2011, 94(1):156-163
20. Straker LM, Abbott RA, Smith AJ. To remove or to replace traditional electronic games? A crossover randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children aged 10-12 years. *BMJ Open* 2013, 3(6). doi:10.1136/bmjopen-2013-002629. Print 2013.
21. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000, 32(9 Suppl):S498-S504.
22. Chaput JP, Leblanc AG, McFarlane A, Colley RC, Thivel D, Biddle SJ, Maddison R, Leatherdale ST, Tremblay MS. Active Healthy Kids Canada's Position on Active Video Games for Children and Youth. *Paediatr Child Health* 2013, 18(10):529-32.
23. Kakinami L, O'Loughlin EK, Dugas EN, Sabiston CM, Paradis G, O'Loughlin J. The Association Between Exergaming and Physical Activity in Young Adults. *J Phys Act Health* 2014. [Epub ahead of print]
24. O'Loughlin E, Sabiston CM, Dugas EN, O'Loughlin JL. The Association Between Exercise Behavior Regulation and Exergaming in Adolescents. *J Phys Act Health*. 2014 May 9. [Epub ahead of print]
25. De Groot, Simons M, de Vet E. Energy intake during active gaming compared to during non-active gaming and watching TV. Submitted.
26. Lyons EJ, Tate DF, Ward DS, Wang X: Energy intake and expenditure during sedentary screen time and motion-controlled video gaming. *Am J Clin Nutr* 2012, 96(2):234-239. 33.
27. Mellecker RR, Lanningham-Foster L, Levine JA, McManus AM: Energy intake during activity enhanced video game play. *Appetite* 2010, 55(2):343-347.
28. Chaput JP, Visby T, Nyby S, Klingenberg L, Gregersen NT, Tremblay A, Astrup A, Sjodin A: Video game playing increases food intake in adolescents: a randomized crossover study. *Am J Clin Nutr* 2011, 93(6):1196-1203
29. Chin A Paw MJ, Jacobs WM, Vaessen EP, et al. The motivation of children to play an active video game. *J Sci Med Sport* 2008; 11:163-166.

30. Paez S, Maloney A, Kelsey K, et al. Parental and environmental factors associated with physical activity among children participating in an active video game. *Pediatr Phys Ther* 2009; 21:245–253.
31. Gardner B, Bruijn G, Lally P. A systematic review and meta-analysis of applications of the Self-Report Habit Index to nutrition and physical activity behaviours. *Ann Behav Med* 2011, 28;42(2):174–187. doi: 10.1007/s12160-011-9282-0
32. Staiano AE, Abraham AA, Calvert SL: Adolescent exergame play for weight loss and psychosocial improvement: a controlled physical activity intervention. *Obesity* (Silver Spring) 2013, 21(3):598–601. doi:10.1002/oby.20282.
33. Trost SG, Sundal D, Foster GD, Lent MR, Vojta D (2014) Effects of a Pediatric Weight Management Program With and Without Active Video Games: A Randomized Trial. *JAMA Pediatr*. doi: 10.1001/jamapediatrics.2013.3436. [Epub ahead of print]
34. Maloney AE, Bethea TC, Kelsey KS, Marks JT, Paez S, Rosenberg AM, Catellier DJ, Hamer RM, Sikich L. A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. *Obesity* (SilverSpring) 2008, 16(9):2074–2080. doi:10.1038/oby.2008.295.
35. Kelder SH, Perry CL, Klepp KI, Lytle LL. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *Am J Public Health*. 1994 Jul;84(7):1121–6.
36. Alberga AS, Sigal RJ, Goldfield G, Prud'homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes*. 2012, 7(4):261–73. doi: 10.1111/j.2047-6310.2011.00046.x. Epub 2012 Mar 28
37. Steinbeck K, Baur L, Cowell C, Pietrobelli A. Clinical research in adolescents: challenges and opportunities using obesity as a model. *Int J Obes (Lond)* 2009, 33(1):2–7. doi: 10.1038/ijo.2008.263. Epub 2008 Dec 9.
38. Cole TJ, Faith MS, Pietrobelli A, Heo M. What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? *Eur J Clin Nutr*. 2005 Mar;59(3):19–25. Erratum in: *Eur J Clin Nutr*. 2005 Jun;59(6):807.
39. Statistics Netherlands, 2011. www.cbs.nl (accessed 7.06.11).
40. Relton C, Torgerson D, O'Cathain A, Nicholl J. Rethinking pragmatic randomised controlled trials: introducing the “cohort multiple randomised controlled trial” design. *Bmj*. 2010;340:c1066.
41. Chinapaw MJ, Mokkink LB, van Poppel MN, van Mechelen W, Terwee CB. Physical activity questionnaires for youth: a systematic review of measurement properties. *Sports Med*. 2010 Jul 1;40(7):539–63. doi: 10.2165/11530770-000000000-00000.
42. Lubans DR, Hesketh K, Cliff DP, Barnett LM, Salmon J, Dollman J, Morgan PJ, Hills AP, Hardy LL. A systematic review of the validity and reliability of sedentary behaviour measures used with children and adolescents. *Obes Rev*. 2011 Oct;12(10):781–99. doi: 10.1111/j.1467-789X.2011.00896.x. Epub 2011 Jun 16.
43. Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. *Pediatrics* 2014, 134(3):e723–31. doi: 10.1542/peds.2014-1012.

44. Dewar DL, Morgan PJ, Plotnikoff RC, Okely AD, Collins CE, Batterham M, Callister R, Lubans DR. The nutrition and enjoyable activity for teen girls study: a cluster randomized controlled trial. *Am J Prev Med*. 2013 Sep;45(3):313-7. doi: 10.1016/j.amepre.2013.04.014.
45. Maddison R, Mhurchu CN, Jull A, Jiang Y, Prapavessis H, Rodgers A. Energy expended playing video console games: an opportunity to increase children's physical activity? *Pediatr Exerc Sci*. 2007 Aug;19(3):334-43.
46. Crouter SE, Flynn JI, Bassett DR Jr. Estimating Physical Activity in Youth Using a Wrist Accelerometer. *Med Sci Sports Exerc*. 2014 Sep 9. [Epub ahead of print].
47. Baranowski T, Abdelsamad D, Baranowski J, O'Connor TM, Thompson D, Barnett A, Cerin E, Chen TA: Impact of an active video game on healthy children's physical activity. *Pediatrics* 2012, 129(3):e636–e642
48. Must A and Anderson SE. Pediatric mini review. Body mass index in children and adolescents: considerations for population-based applications. *International Journal of Obesity* 2006, 30, 590–594. doi:10.1038/sj.ijo.0803300.
49. Ridder MAM, Heuvelmans MA, Visscher TLS, Seidell JC, Renders CM, (2010) “We are healthy so we can behave unhealthily: A qualitative study of the health behaviour of Dutch lower vocational students”. *Health Education*, 2010, 110 (1): 30 - 42
50. Cummings HM, Vandewater EA. Relation of adolescent video game play to time spent in other activities. *Arch Pediatr Adolesc Med* 2007, 161(7):684-9.
51. Przybylski AK. Electronic gaming and psychosocial adjustment. *Pediatrics*. 2014 Sep;134(3):e716-22. doi: 10.1542/peds.2013-4021. Epub 2014 Aug 4.
52. Michael DR, Chen S. Serious Games Defined. In *Serious games that entertain, educate train and inform*. Boston: Thomson Course Technology: 2006: 17-27
53. Ritterfeld U, Cody MJ, Vorderer P. *Serious games: Mechanisms and effects*. Taylor & Francis Ltd. 2009.
54. King D, Greaves F, Exeter C and Darzi A. ‘Gamification’: Influencing health behaviours with games. 2013 *J R Soc Med* 2013; 106:76-78. DOI: 10.1177/0141076813480996
55. Deterding S, Miguel S, Nacke L, O'Hara K, Dixon D, editors. Gamification. Using game-design elements in non-gaming contexts. In Part 2. Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems, pp. 2425–2428. ACM. 2011
56. Prensky, 2011. *Fun, Play and Games: What Makes Games Engaging* (chapter 5). In: *Digital Game-Based Learning*. McGraw-Hill, 2001
57. Cugelman B. Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers. *JMIR Serious Games* 2013;1(1):e3. doi:10.2196/games.3139
58. DeSmet A, Van Ryckeghem D, Compennolle S, Baranowski T, Thompson D, Crombez G, Poels K, Van Lippevelde W, Bastiaensens S, Van Cleemput K, Vandebosch H, De Bourdeaudhuij I. A meta-analysis of serious digital games for healthy lifestyle promotion. *Prev Med*. 2014, 27;69C:95-107. doi: 10.1016/j.ypmed.2014.08.026. [Epub ahead of print] Review.

59. Baranowski T, Baranowski J, Thompson D, Buday R, Jago R, Griffith MJ, Islam N, Nguyen N, Watson KB. Video game play, child diet, and physical activity behavior change a randomized clinical trial. *Am J Prev Med*. 2011 Jan;40(1):33-8. doi: 10.1016/j.amepre.2010.09.029.
60. Simons M, Baranowski J, Thompson, D, Buday R, Abdelsamad D, Baranowski T. Child Goal Setting of Dietary and Physical Activity in a Serious Videogame. *Games Health J* 2013; 3(2): 150-157
61. Johnson-Glenberg MC, Savio-Ramos C, Hue H. "Alien Health". A Nutrition Instruction Exergame Using the Kinect Sensor. *Games for Health Journal*. August 2014, 3(4): 241-251. doi:10.1089/g4h.2013.0094.
62. Middelweerd A, Mollee JS, van der Wal C, Brug J, Te Velde SJ. Apps to promote physical activity among adults: a review and content analysis. *Int J Behav Nutr Phys Act*. 2014;11(1):97. [Epub ahead of print]
63. Direito A, Dale LP, Shields E, Dobson R, Whittaker R, Maddison R. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? *BMC Public Health*. 2014 Jun 25;14:646. doi: 10.1186/1471-2458-14-646.
64. Lister C, West JH, Cannon B, Sax T, Brodegard D. Just a Fad? Gamification in Health and Fitness Apps. *JMIR Serious Games* 2014;2(2):e9. DOI: 10.2196/games.3413
65. Boulos MN, Yang SP. Exergames for health and fitness: the roles of GPS and geosocial apps. *Int J Health Geogr*. 2013 Apr 5;12:18. doi: 10.1186/1476-072X-12-18.
66. <https://www.zombiesrungame.com/>
67. Bacigalupo R, Cudd P, Littlewood C, Bissell P, Hawley MS, Buckley Woods H. Interventions employing mobile technology for overweight and obesity: an early systematic review of randomized controlled trials. *Obes Rev*. 2013, 14(4):279-291. doi: 10.1111/obr.12006. <http://dx.doi.org/10.1111/obr.12006>.
68. O'Malley G, Dowdall G, Burls A, Perry IJ, Curran N. Exploring the Usability of a Mobile App for Adolescent Obesity Management. *JMIR Mhealth Uhealth*. 2014, 2(2): e29. doi: 10.2196/mhealth.3262
69. Carter MC, Burley VJ, Nykjaer C, Cade JE. Adherence to a Smartphone Application for Weight Loss Compared to Website and Paper Diary: Pilot Randomized Controlled Trial. *J Med Internet Res*. Apr 2013; 15(4): e32.
70. Jongert MWA, Claessens M, van der Heijden E. Beweegstimulerend door middel van een innovatieve buitenspeelhulp, de Swinx. TNO 2009. KvL/GB 2009.072.
71. Playfit onderzoek, 2014. Available at: <http://www.playfitproject.nl/ebooks/>
72. Simons M, Vries SI de, Jongert MWA. Energy expenditure of three public and three home based active computer games in children. *Computers in Entertainment: Theoretical and Practical Computer Applications in Entertainment*, Vol. 12, No. 1 (March 2014). DOI: 10.1145/2543698.2543701
73. Simons M, Opdam L, van Empelen P. Feasibility of an Active Game Program in a Dutch Pre-Vocational High School Setting. *Games Health J* 2013;6(2):332-340.

74. Hoornstra S, de Vet E, Steenhuis I, de Boer M. De E-Fit fiets op de basisschool: Onderzoek naar de effectiviteit van de e-fit fiets als middel om kinderen meer te laten bewegen (in Dutch). Vrije Universiteit Amsterdam, 2010.
75. Duncan JM, Staples V. The impact of a school-based active video game play intervention on children's physical activity during recess. *Hum Movement* 2010; 11:95–99.
76. De Bourdeaudhuij I, Van Cauwenberghe E, Spittaels H, Oppert JM, Rostami C, Brug J, Van Lenthe F, Lobstein T, Maes L. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. *Obes Rev*. 2011 Mar;12(3):205–16. doi: 10.1111/j.1467-789X.2009.00711.x.
77. Papastergiou M. Exploring the potential of computer and video games for health and physical education: A literature review. *Comput Educ* 2009; 53:603–122.
78. Gao Z, Zhang T, Stodden D. Children's physical activity levels and psychological correlates in interactive dance versus aerobic dance. *J Sport Health Sci* 2013; 2:146–151.
79. Sun H. Impact of exergames on physical activity and motivation in elementary school students: A follow-up study. *J Sport Health Sci* 2013; 2:138–145.
80. Schermers P, Bakker I, de Vries SI, Jongert, MWA. Evaluatie YalpSona. TNO 2008. KvL/B&G 2008.047
81. Ferguson B. Games for Wellness—Impacting the Lives of Employees and the Profits of Employers. *Games for Health Journal: Research, Development, and Clinical Applications* 2012, 1 (3). doi: 10.1089/g4h.2012.0023
82. Simons M, Hildebrandt, V. Lasersquash als hightech werkpleksport. *Preventie* 2008; 4.
83. Van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med*. 2012;172(6):494–500
84. Simons M. Lichamelijke belastingintensiteit van Lasersquash. 2007. TNO rapport Leiden. KvL/B&G/2007.033.
85. Staiano, AE and Flynn R. Therapeutic Uses of Active Videogames: A Systematic Review. *Games for Health Journal*. December 2014, 3(6): 351–365. doi:10.1089/g4h.2013.0100.
86. Staiano AE, Abraham AA, Calvert SL. Motivating effects of cooperative exergame play for overweight and obese adolescents. *J Diabetes Sci Technol* 2012 Jul 1;6(4):812–9.
87. Lyons EJ, Hatkevich C. Prevalence of behavior changing strategies in fitness video games: theory-based content analysis. *J Med Internet Res*. 2013 May 7;15(5):e81. doi: 10.2196/jmir.2403.
88. Brug J, Oenema A, Ferreira I. Theory, evidence and Intervention Mapping to improve behavior nutrition and physical activity interventions. *International Journal of Behavioral Nutrition and Physical Activity* 2005, 2:2 doi:10.1186/1479-5868-2-2
89. Straker LM, Fenner A, Howie EK, Feltz D., Gray CM, Lu Amy Shirong, Mueller F, Simons M, Barnett LM. *Games for Health Journal*. Online ahead of print. doi:10.1089/g4h.2014.0077.
90. Biddiss E, Irwin J: Active video games to promote physical activity in children and youth: a systematic review. *Arch Pediatr Adolesc Med* 2010, 164(7):664–672