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Artículos Originales

Use of Educational Technology in Promoting Health Awareness among School Students: Results of a Meta-analysis

Uso de la tecnología educativa para promover la conciencia sobre la salud en estudiantes escolares: Resultados de un meta-análisis'.

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Abstract

Research examining the effectiveness of technology-supported interventions on health-related knowledge acquisition and behavior modification among school children is scant. This meta-analysis reviewed the impact on knowledge acquisition, development of favorable attitudes towards healthy lifestyles, and the adoption of healthy practices among school students exposed to interactive educational technologies as compared to those exposed to technology-free classroom-based health education. Of 236 pertinent articles identified through systematic literature searches, 25 primary empirical studies met the inclusion criteria; half of these were published in and after 2015. Meta-analysis showed strong evidence of the beneficial effects of integrating educational technology into instructional practices, significantly improving the health-related knowledge of school students (g+ = 0.50, $p < .01$). Smaller, yet statistically significant effects were found on the development of positive attitude towards healthy lifestyles and the adoption of healthy behaviors. Despite some limitations, the study consistently indicates that school-based technology-supported interventions can improve outcomes pertinent to healthy lifestyles, including knowledge, attitudes, behaviors and practices of learners. Raising awareness and adopting healthy practices are necessary as early measures of success in preventing childhood among school students.

Keywords: Health promotion programs, educational technology, meta-analysis, schools, K-12, healthy lifestyle.

Resumen

Son escasas las investigaciones que examinan la eficacia de las intervenciones apoyadas por la tecnología en la adquisición de conocimientos relacionados con la salud y la modificación del comportamiento entre los escolares. Este meta-análisis revisó el impacto en la adquisición de conocimientos, el desarrollo de actitudes favorables hacia estilos de vida saludables y la adopción de prácticas saludables entre los estudiantes escolares expuestos a tecnologías educativas interactivas en comparación con aquellos expuestos a la educación en salud basada en el aula sin tecnología. De los 236 artículos pertinentes identificados mediante búsquedas bibliográficas sistemáticas, 25 estudios empíricos primarios cumplieron los criterios de inclusión; la mitad de ellos se publicaron en 2015 y después de esa fecha. El metaanálisis mostró pruebas sólidas de los efectos beneficiosos de la integración de la tecnología educativa en las prácticas de instrucción, lo que mejoró significativamente los conocimientos relacionados con la salud de los alumnos de las escuelas (g+ = 0,50, $p < 0{,}01$). Se encontraron efectos más pequeños, aunque estadísticamente significativos, en el desarrollo de una actitud positiva hacia los estilos de vida saludables y la adopción de comportamientos saludables. A pesar de algunas limitaciones, el estudio indica consistentemente que las intervenciones apoyadas por la tecnología en las escuelas pueden mejorar los resultados pertinentes a los estilos de vida saludables, incluyendo el conocimiento, las actitudes, los comportamientos y las prácticas de los estudiantes. La concientización y la adopción de prácticas saludables son necesarias como medidas tempranas de éxito en la prevención de la infancia entre los estudiantes de la escuela.

Palabras clave: Programas de promoción de la salud, tecnología educativa, meta-análisis, escuelas, K-12, estilo de vida saludable.

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‘Use of Educational Technology in Promoting Health Awareness among School Students: Results of a Meta-analysis’

Healthy life style habits not only reduce health care costs, but also contribute to increased longevity and enhanced quality of life. As the disease burden in developed countries shifted from infectious to chronic conditions, major emphasis is now placed on modifiable risk behaviors, namely lack of physical activity, poor nutrition, tobacco use and alcohol consumption (Mokdad, Marks, Stroup, & Greberding, 2004). This issue is not exceptional to the economically affluent world. Along with economic development and income growth, the adoption of lifestyles resembling those of developed societies has yielded the unprecedented rise in chronic diseases in many developing countries (Müller, Alley, Schoeppe, & Vandelanotte, 2016). Non-communicable diseases associated with these risk behaviors are not only the most common, deadly and costly, but are the most preventable. One study reported that all causes of mortality can be reduced by 55% if people refrain from smoking, engage in regular physical activity, eat a healthy diet and maintain normal body weight (Van Dam, Li, Spiegelman, Franco, & Hu, 2008). Other prospective studies reported consistent associations of both overweight and obesity with higher all-cause mortality in four continents (Di Angelantonio et al., 2016). However, modifying risky behaviors is a very challenging task for public health practitioners.

As it is easier to prevent detrimental health habits than to change them after they have become deeply rooted in the daily practices of individuals, then attention needs to be focused on preventing children and adolescents from adopting risk behaviors. This can be achieved by implementing health promotion programs in schools; these programs provide students with the basic knowledge needed to prevent illness and promote health. Several behavior change theories consider knowledge of health risks and benefits of different health practices as a core pre-requisite of change. The Information-Motivation-Behavioral Skills Model, for example, considers the constructs of information, motivation and behavioral skills as fundamental determinants of preventive behavior (Fisher, Fisher, & Shuper, 2009). The Social Cognitive Theory, another model used to explain and modify behavior, relies on informing people about health issues as this creates the pre-condition for change (Bandura, 2004). If people do not possess the knowledge about the impact of their lifestyles on their health, then they will be less motivated to forgo unhealthy habits that they enjoy. Hence, schools are the prime sites for imparting health-related knowledge to their students. When properly implemented, school health promotion programs can curtail the risk behavior among children that may jeopardize their health as adults later on.

School health promotion programs can be more effective in meeting their objectives if they incorporate the interactive capabilities of electronic technologies in their programs. The information revolution has created a generation who are accustomed to learning in rich audio-visual environments (Wyatt & Hauenstein, 2008). In addition, these technologies can deliver health education material that is fun to read. Studies to improve students’ literacy levels have shown that not only students enjoy electronic books more than printed ones, but students also remember the content more clearly and answer comprehension questions more quickly (Korat and Shamir, 2008). The systematic review by Hieftje, Edelman, Camenga, and Fiellin (2013) showed that interventions using electronic media could improve health and safety behaviors in young persons. In a study of students’ perception about a smartphone application designed to promote physical activity, most participants reported that the multi-component intervention provided them with new skills, techniques and habits for the future (Lubans, Smith, Skinner & Morgan, 2014). Another systematic review conducted to investigate the effectiveness of electronic and mobile health (e-& mHealth) interventions in promoting physical activity and healthy diets, suggested that e-& mHealth interventions can be effective in improving physical activity and diet quality in developing countries (Müller, Alley, Schoeppe & Vandelanotte, 2016). In sum, the scientific evidence of technology-supported interventions in inducing a change in health behavior is mounting. There is reason to believe that integrating interactive technologies in school-based health promotion programs can have a long-lasting impact on children's acquisition of healthy lifestyle habits. However, to the best of our knowledge, there exist no meta-analysis studies comparing the effectiveness of school health promotion programs delivered with the use interactive technologies to those where technology was not integrated. Therefore, the objective of this review is to compare the outcomes of interactive technologies use in school health promotion programs to those of traditional methods of raising health awareness. More specifically, the review assesses the impact on knowledge acquisition, development of attitudes towards healthy style, and adoption of healthy practices among students. The findings can inform decision makers about the importance of integrating interactive educational technologies in school health curricula.

Research Questions

This review focuses on summarizing empirical research findings regarding the effects of technology-supported instructions aimed at the promotion of healthy life-style in compulsory (K-12) school students on a broad variety of their cognitive, attitudinal, and behavioral outcomes. It synthesizes research evidence on the instructional practices using computer-based educational technology to enhance teaching and learning of the content, related to the prevention of obesity and unhealthy behaviors and the promotion of physical activity, healthy behaviors and good eating habits.

Specifically, this study, employing the methodology of meta-analysis, addressed the following research question:

What are the weighted average effect sizes of technology-supported versus technology- free instructions on topics related to health promotion as reflected by students' learning outcomes?

To clarify, the following set of secondary questions was explored:

Q1: Do school-based, technology-supported interventions affect health-related knowledge of students?

Q2: Do school-based, technology-supported interventions affect health-related attitude of students?

Q3: Do school-based, technology-supported interventions affect health-related practice of students?

Q4: Do school-based, technology-supported interventions affect unhealthy food intake?

Q5: Do school-based, technology-supported interventions affect students' Body Mass Index (BMI)?

Q6: Do school-based, technology-supported interventions affect self-reported physical activity of students?

Outcome Measures

The students' learning outcomes will be evaluated by following the Knowledge Attitude Practice (KAP) model, a widely used framework in health education research. In the KAP model, knowledge is defined as the acquisition, retention and use of information. It is a mixture of education and experience. Attitude is defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly & Chaiken, 1993, p. 1). Practice refers to behaviors or actions that can halt a disease or delay its onset and /or progression. In particular, a health-related practice is a composite index including physical activity, healthy food intake, and healthy habits. According to the KAP model, healthy behavior occurs due to healthy attitude, which is formed due to knowledge about healthy lifestyle practices (Wan, Rav-Marathe, & Marathe, 2016). Our set of research questions, in a way, is intended to test this model on a broad variety of relevant empirical data.

METHOD

Search Strategy and Data Sources

To locate relevant studies for the review, an array of bibliographic databases was searched, including both discipline-specific and multi-disciplinary resources. The searches were performed between April and July of 2017. The following databases were used: Academic Search Complete, Biosis Previews, Communication Abstracts, Communication & Mass Media Complete, Computers & Applied Sciences Complete, Education Source, ERIC, Medline, ProQuest Central, ProQuest Dissertations & Theses Global, PsycINFO, SPORT Discus, and Web of Science.

Search results were required to contain at least one term from each of three sets of keywords for the following main concepts: 1) Health/Nutrition Education, 2) Educational Technology, 3) K-12 Population. For example, the following combinations were used in the searches:

("Health Education" OR "Health Literacy" OR "Health* Attitude*" OR Nutrition OR "Health Promotion" OR …)

AND

("Educational Technolog*" OR "Information Technolog*" OR Computer* OR Simulation OR "Computer Gam*" OR "Video Gam*" OR "Blended Learning" OR …)

AND

(Elementary OR "Primary Education" OR "Primary School*" OR "Middle School*" OR "High School*" OR kindergarten OR …)

All searches were conducted by a library science expert and, wherever possible, the strategy was tailored to the available features of a database, for instance by using official controlled vocabulary subject headings or grade/age level filters.

The search of bibliographic databases was supplemented by a separate strategy to locate grey literature (Schöpfel & Farace, 2010). The primary tool employed was the Google search engine, as well as two websites: LearnTechLib (the online library of the Association for the Advancement of Computing in Education) and OpenGrey.eu (an open access collection of grey literature produced in Europe). An exhaustive single search statement is not possible using Google, so a series of searches were run, varying the keywords employed. The first 5 pages of results were reviewed for relevant material.

The searches produced 2,484 results, of which 1,969 abstracts were retained for review after duplicates were removed.

Inclusion/Exclusion Criteria

The following criteria for a study inclusion in the meta-analysis were used:

1. Research was conducted in formal educational settings of compulsory education (grades K through twelve) on topics related to diabetes awareness.
2. Study research design complied with the standards of either randomized control trials (RCT) or high-quality quasi-experiments.
3. Study addressed an independent comparison of learning outcomes between an experimental (technology-supported) condition and those of a control (technology-free) condition in one of the categories listed earlier in the Research Question section.
4. Study contained statistical information sufficient for the effect size extraction.

Review Procedure

Two researchers (the second and third authors of the paper) reviewed each study identified by searches, first at the abstract level. Then those selected through the screening were reviewed at the level of full-text documents using the inclusion criteria. Finally, the reviewers discussed disagreements, when necessary inviting the third opinion. The same procedure was implemented at the stage of effect size extraction and moderator variables coding, at which the reviewers also ensured that only independent samples of participants were admitted and that measures of learning outcomes were categorized according to the list outlined in the Research Questions section. Inter-rater agreement rates for each of the review stages, expressed as Cohen’s kappa coefficients, were calculated and are reported in the Results section.

Moreover, some study characteristics were coded as potential moderator variables. Specifically, in the included research reports and document we tried to find the following information:

Student-related variables:
- Age and/or grade level;
- Socio-economic status;

School-related variables:
- Geographical region;
- School type: public or private;

Intervention-related variables:
- Duration of the instructional intervention;
- Parents' involvement in implementing instructional interventions under investigation; and
- Control group's use of some kind of educational technology.

Effect Size Extraction and Aggregation

Routinely for intervention-type studies, effect sizes were extracted as Cohen’s d or standardized mean difference. Whenever descriptive statistics were not available, for effect size calculation inferential statistics, such as t-tests, F-tests, or exact p-values were used as described in Glass, McGaw and Smith (1981) and Hedges, Shymansky and Woodworth (1989). These effects then were converted into Hedges’ g as a correction for small sample bias (Hedges & Olkin, 1985). This meta-analysis applied both the random effects and the fixed effect models for aggregating extracted effect sizes (Borenstein et al., 2009). The weighted average point estimate, calculated by means of the former model, is more appropriate to represent the true effect of the intervention in the population of this type of educational research, while the latter analysis produces an estimate of heterogeneity of the distribution of effect sizes to decide on the need of subsequent moderator variable analyses intended to explain systematic variations in findings using the mixed effects analytical model (Borenstein et al., 2010; Higgins, Thompson, Deeks & Altman, 2003).

RESULTS

Out of 1,969 empirical studies, our systematic searches found, 236 were identified as potentially relevant for the purposes of this meta-analysis. This number was further reduced at the full-text review stage to results in the overall 25 primary empirical studies that together produced 48 independent effect sizes in six categories of examined learning outcomes.

We calculated inter-rated agreement rates for each respective stage of the review. These are reported below:

- Retrieval decisions (at the abstract review level) – Cohen’s kappa = 0.76;
- Inclusion/Exclusion decisions (at the full-text review level – Cohen’s kappa = 0.88);
- Identifying outcome category and extracting effect sizes – Cohen’s kappa = 0.70.
- Study features coding – Cohen’s kappa = 0.82.

EFFECT SIZES BY OUTCOME CATEGORY

Summary tables below report findings of this meta-analysis. These are weighted average effect sizes and the corresponding heterogeneity statistics in all six categories of learning outcomes. Results produced by analyses in both random and fixed models are also reported there. The former is used to most reliably estimate the respective effect of the treatment in the population, while the latter produces heterogeneity estimates (see assumptions for selecting the appropriate analytical model in Borenstein et al., 2010).

Table 1 summarizes findings within the Knowledge outcome category. Overall, nine effect sizes produced the weighted average of g+ = 0.500, statistically significant at p < .01. They were based on performance of 5,123 (2,712 experimental and 2,411 control) students and ranged in magnitude from g = –0.071 (Sharma et al., 2014) to g = 1.102 (Hung et al., 2009). Though eight out of nine effects in this category were positive, they were widely dispersed. The heterogeneity measure: QTotal = 90.08 (p < .01). No publication bias that would require adjustment to the weighted average effect size was detected.

Table 1. *Overall average weighted effect size (random effects model) for the final collection based on* ***Knowledge*** *outcomes and heterogeneity statistics (fixed effect model)*

Population Estimates	*k*	*g+*	*SE*	Lower 95th	Upper 95th
Random Effects Model	9	0.500**	0.119	0.267	0.733
Fixed Effect Model	9	0.612**	0.029	0.555	0.668

** *p* < .01

Heterogeneity Analysis $Q_T = 90.08$ ($df = 8$), $p < .01$, $I^2 = 91.12$

The summary of results with respect to attitudinal outcomes are presented in Table 2. The overall weighted average effect size reflecting formation of positive attitude among the students was $g^+ = 0.296$ ($p < .01$). However, according to the trim and fill analysis, imputation of potentially missing (due to possible publication bias) effects on the negative side of the distribution could lead to the reduction in the point estimate from the observed one to $g^+ = 0.089$ and render it statistically non-significant. Significantly heterogeneous distribution of the effects ($Q_{Total} = 44.43$, $p < .01$) spreading from $g = –0.297$ (Zhu & Dragon, 2016) to $g = 0.638$ (Sharma et al., 2014) contained twelve positive and one negative effect size and was based on data collected from 2,628 individual students (1,450 – in the treatment and 1,178 – in the control conditions, respectively).

Table 2. *Overall average weighted effect size (random effects model) for the final collection based on* ***Attitudinal*** *outcomes and heterogeneity statistics (fixed effect model)*

Population Estimates	*k*	*g+*	*SE*	Lower 95th	Upper 95th
Random Effects Model	13	0.296**	0.091	0.117	0.474
Fixed Effect Model	13	0.221**	0.040	0.143	0.299

** $p < .01$

Heterogeneity Analysis $Q_T = 44.43$ ($df = 12$), $p < .01$, $I^2 = 72.99$

Table 3 summarizes data about the effects of technology-supported interventions on the composite index of adherence to the recommended guidelines for promoting healthy practices (including physical activity, healthy food intake, and healthy habits that reduce risk of obesity and diabetes). The overall weighted average effect size of $g^+ = 0.243$ was statistically significant ($p = .023$), but relatively low in magnitude. Moreover, statistical adjustment (imputation of potentially missing negative effects) to compensate for the influence of publication bias would bring it down to statistically non-significant $g^+ = 0.137$. Based on a total sample of 4,251students (2,218 – experimental and 2,033 – control), the distribution of individual effects was significantly heterogeneous ($Q_{Total} = 111.75$, $p < .001$) ranging from $g = –1.139$ (Zhu & Dragon, 2016) to $g = 1.093$ (Barbee & Bennett, 2016) and included five negative and eleven positive effect sizes.

Table 3. *Overall average weighted effect size (random effects model) for the final collection based on* ***Combined "Physical Activity', 'Healthy Food Intake', and 'Healthy Habits'*** *outcomes and heterogeneity statistics (fixed effect model)*

Population Estimates	*k*	*g+*	*SE*	Lower 95th	Upper 95th
Random Effects Model	16	0.243*	0.107	0.033	0.453
Fixed Effect Model	16	0.161**	0.031	0.100	0.222

* $p < .05$; ** $p < .01$

Heterogeneity Analysis $Q_T = 111.75$ ($df = 15$), $p < .001$, $I^2 = 86.58$

Table 4 summarizes findings in the "Unhealthy Food Intake" outcome category. Calculated on the basis of four individual cases and encompassing 889 students, the overall weighted average effect size of $g^+ = 0.294$, was statistically significant ($p < .01$) and marginally homogeneous ($p = .052$). All individual effects were positive and ranged from $g = 0.115$ (Smith et al., 2015) to $g = 0.599$ (Sharma et al., 2014).

Table 4. *Overall average weighted effect size (random effects model) for the final collection based on "****Unhealthy Food" Intake*** *outcomes and heterogeneity statistics (fixed effect model)*

Population Estimates	*k*	*g*+	*SE*	Lower 95th	Upper 95th
Random Effects Model	4	0.294**	0.114	0.070	0.518
Fixed Effect Model	4	0.257**	0.068	0.124	0.391
** *p* < .01					
Heterogeneity Analysis	$Q_T = 7.72$ ($df = 3$), $p = .052$, $I^2 = 61.14$				

Tables 5 and 6 report the summary of findings for the outcome categories of Self-Reported Physical Activity and Body Mass Index, respectively. The corresponding weighted average effect sizes of $g^+ = 0.225$ and $g^+ = 0.019$ were non-significant. Any interpretation of these results should be cautious, as both collections counted only three individual effect sizes, unlikely to be sufficiently representative of the entire population. Moreover, the respective sample sizes were also rather limited: 661 students in the first and 575 students in the second outcome category. However, it is worth mentioning that individual effects were positive in either outcome category. As it would be expected for collections with so few cases, both were homogeneous.

Table 5. *Overall average weighted effect size (random effects model) for the final collection based on* ***Self-Reported Physical Activity*** *outcomes and heterogeneity statistics (fixed effect model)*

Population Estimates	*k*	*g*+	*SE*	Lower 95th	Upper 95th
Random Effects Model	3	$0.225^{(ns)}$	0.123	-0.015	0.466
Fixed Effect Model	3	0.183*	0.078	0.030	0.335
* *p* = .019					
Heterogeneity Analysis	$Q_T = 2.88$ ($df = 2$), $p = .24$, $I^2 = 30.51$				

Table 6. Overall average weighted effect size (random effects model) for the final collection based on ***Body Mass Index (BMI)*** outcomes and heterogeneity statistics (fixed effect model)

Population Estimates	*k*	*g*+	*SE*	Lower 95th	Upper 95th
Random Effects Model	3	$0.019^{(ns)}$	0.083	-0.145	0.182
Fixed Effect Model	3	0.019	0.083	-0.145	0.182
Both models – non-significant					
Heterogeneity Analysis	$Q_T = 0.139$ ($df = 2$), $p = .93$, $I^2 = 0.00$				

Several categories of study characteristics were coded as described in the Method section to possibly be used in capacity of moderator variables for explaining systematic variability in documented effect sizes. Unfortunately, information for some (e.g., socio-economic status of the students' families or public vs. private status of the school settings in questions) was not reported in the majority of the studies admitted to this meta-analysis. Also, as summary tables above clearly indicate, three out of six investigated outcome categories were represented by too few cases to enable a proper moderator variable analysis. In other three outcome categories, the levels of the majority of coded moderator variable were represented by disproportionate number of cases, also violating conditions for meaningful interpretation of the corresponding between-level statistical comparisons.

Nevertheless, some observations could be reported descriptively. For example, there was a tendency toward higher effects of the interventions that somehow involved students' parents into their implementation (e.g., Struempler et al., 2016: g = 0.786 in the Knowledge outcome category; or González-Cutre, 2014: g = 0.555 in the Attitudes outcome category). Neither age of learners, nor geographic area significantly influenced the magnitude of the intervention effects. However, with respect to duration of the treatment, there was an overall trend for longer interventions to produce higher outcomes (e.g., Shen, Hu, & Sun, 2015: g = 0.821 & g = 0.591 in the Knowledge and Attitudes outcome categories, respectively)

DISCUSSION

To researchers' knowledge, this is the first meta–analysis of the effects of technology-supported interventions on the health-related knowledge acquisition and behavior modification among school children. Despite the modest number of studies that met our inclusion criteria, there was a strong evidence (0.500, 95% CI: 0.267 to 0.733) of the beneficial effects of integrating technology-supported instruction on significantly improving the health-related knowledge of school students. Our findings also suggest a statistically significant effect of computer-based interventions on the formation of positive attitude towards healthy lifestyle, although the effect size was low to moderate (0.296, 95% CI: 0.117 to 0.474). These findings, as predicted, are consistent with those reported by Papastergiou (2009) who found that the use of electronic games as educational tools might improve young people's knowledge, skills, attitudes and behaviors in relation to health and physical exercise. One article included in this review investigated the relationship of 'Knowledge in Action' fitness lessons on the acquisition of health-related fitness knowledge (Hodges, Kulinna & Mars, 2016). This study showed that this technology-supported fitness intervention was a predictor of health-related fitness knowledge. To examine the improvements in children's health-related knowledge, attitudes and behaviors, Palmer, Graham, and Elliot (2005) evaluated the impact of the e-Learning module on the middle-school students' physical activity knowledge, attitudes and behaviors. The researchers found that the 5th grade students' health-related fitness knowledge could be significantly increased through a sound web-based program, which was also seen to positively affect participants' attitudes toward physical activity. Similar finding was reported by the meta-analysis by Edwards, Noyes, Lowes, Spencer and Gregory (2014) who determined the effectiveness of educational interventions on children with Type 1 Diabetes. Their major finding was that educational interventions significantly increased knowledge and confidence of children. However, this result needs to be interpreted with caution as it is not clear if the interventions were technology-supported.

Back in 1993, Goldfine and Nahas reported that if students possess information about health-related fitness benefits, they will be more likely to make informed decisions about exercise and fitness, develop more positive attitudes toward physical activity, and choose more active lifestyles than individuals who were not exposed to such information. Another researcher argues that teaching fitness knowledge in physical education is fundamental in promoting lifelong physical activity (Ennis, 2010). A recent systematic review and meta-analysis of the overall effects of school-based obesity prevention interventions found that emphasizing enjoyment in physical activity sessions was critical for single-component (as opposed to multi-components) physical activity interventions (Liu et al., 2019). Because of their interactive capabilities, students reported that technology-supported interventions were fun (Papastergiou, 2009). In our review, knowledge acquisition had the highest effect size. In order to maximize the impact of knowledge acquisition, schools are encouraged to include technology-supported instructions in their health education/physical activity programs. Adopting such an approach can be a useful public health strategy to combat the epidemic of obesity among school students.

In addition to knowledge acquisition and the development of favorable attitudes, a statistically significant effect of the technology-based interventions on the adoption of healthy practices was found, although the size was small (0.243, 95% CI: 0.033 to 0.453). A similar finding was reported in a systematic review of electronic, media-based health interventions promoting behavior change in youth (Hieftje et al., 2013). However, Hieftje and colleagues called for better quality evaluations of electronic-based interventions. By targeting school-based interventions studied by the RCT and quasi-experimental research, our present meta-analysis has addressed this gap in the current literature. However, this very fact that our review was only limited to school-based interventions may account for the small effect size of the technology-supported interventions on the adoption of healthy practices. Though evidence is supporting the integration of these technologies in the school health promotion curricula, these interventions should not be expected to mitigate the obesigenic factors that students encounter on a daily basis. Interventions at multiple layers of influence are needed to enable students to become resilient to the unhealthy trends in the society at large.

An additional significant effect of technology-based interventions was a reduction in unhealthy food intake (0.294, 95% CI: 0.070 to0.518), another favorable positive practice. This finding is similar to those reported by Cullen, Watson, Baranowski, Baranowski, and Zakeri, (2005) who reported an increase in the consumption of fruit, 100% juice and vegetables by the experimental group who received the technology-based intervention. Vio, Salinas, Montenegro, González, and Lera, (2014) also reported a significant decrease in unhealthy food consumption practice after the implementation of a school-based, technology-supported nutrition education programs for children aged 7-9.

According to the KAP model, people may modify their health and lifestyle behaviors if they have specific knowledge about how their behaviors can increase their disease risk (Xu, Wang, Xiang, Wang, Ye, & Ware, 2017). This model has been extensively used in several health behavior-related studies (WHO, 2008; UNICEF, 2017). Our study provided further evidence to this framework so that better knowledge gained through technology-supported awareness interventions promoted good attitudes and ultimately led to the desirable positive change in behaviors. Hence, school-based, technology-supported intervention are effective in promoting knowledge acquisition, development of favorable attitudes and positive behavioral changes.

This review did not report a significant effect on self-reported physical activity. Caution is needed when interpreting this finding as it is based only on three individual effect sizes. Nevertheless, this lack of significance can be attributed to the short duration of the interventions in the RCT studies that were included in our analysis. An intervention of long-term duration (6 months and longer) was implemented only in one study; in other studies, the interventions lasted from 1 week - 5 months. Hence, short-term interventions might not be strong enough to instill physical activity habits among school students. In addition, self- reported behavioral data can be biased by social desirability and inaccurate responses. A study about self- reported physical activity showed substantial differences in the prevalence estimates between subjective measured physical activity and objective criterion measures (Monyeki, Moss, Kemper, & Twisk, 2018). Thus, for future physical activity research, it is recommended to use a combination of subjective and objective physical activity assessment methods.

As for weight control, our review found that technology-supported interventions did not lead to statistically significant effects on Body Mass Index (BMI). It is worth mentioning that this sub-analysis included only three individual effect sizes, unlikely to be sufficiently representative of the entire population, especially considering that the sample size was 575 students. In the meta-analysis of 12 randomized interventions of school-based physical activities, Guerra, Nobre, Silveira, and Taddei (2013) reported a similar finding. However, there is controversy in the literature about the relationship of school-based interventions and BMI. A review by Katz (2009) clearly demonstrated that school-based interventions had significant effects on weight. This resonates with the findings from Waters et al. (2011) who reported beneficial effects of health-related interventions on the control of childhood obesity based on BMI measurement. However, our review was limited only to interventions within the school premise whereas Waters et al. (2011) review also included out of school interventions. The use of multiple concurrent interventions, duration and intensity of the intervention, and the inclusion of studies with different study designs may explain the discrepancy in the findings of several reviews. The Cochrane Review by Summerbell et al. (2005) reported that a multimedia approach, focusing on physical activity alone, to be effective in preventing childhood obesity. An RCT study showed that a multi-component physical activity intervention for one school year had a favorable result on BMI (Kriemle et al., 2010). An updated Cochrane review (Brown et al., 2019) about preventing childhood obesity reported the effect size that varied as a factor of student age and whether a standalone program or combined interventions were used. In young children aged 0 to 5 years, interventions that included diet combined with physical activity interventions reduced the risk of obesity whereas for students in the age group 6 to 12 years, physical activity interventions reduced obesity risks. Though Brown et al. (2019) reviewed RCT studies, caution should be used when comparing our results with theirs. They included interventions outside the school setting and it was not clear if the interventions were technology-supported.

The studies included in Katz (2009) review incorporated a broad range of interventions to impact the weight status of the student population. Some of these interventions were: classroom (or after-school) instruction; participatory/hands-on, skill-building student activities, provision of print materials, teacher training for program implementation, student competitions, physical activity programs in addition to routine physical education, and training in behavioral techniques or coping skills. Katz (2009) advocated for examining strategies for the optimal blending of these intervention approaches. Developing technology-supported instructions, based on established health promotion theories, will help in addressing this recommendation. In addition to supporting experiential learning, technology-supported instructions can be personalized and can provide immediate feedback to the learner and increase learner engagement (Hieftje et al., 2013). The school will be the ideal setting for the implementation of these technology-supported interventions to promote healthy behavior as schools can foster and motivate the adoption of healthy behaviors from an early age.

To reap the maximum benefits of the school-based technology-supported interventions on BMI, the duration of the intervention should be at least one school year. This one-year period may be sufficient to inspire school students to adopt long lasting healthy practices. However, although the school environment should be conducive to the implementation of interventions aimed at promoting healthy lifestyles and practices that prevent illness, from the ecologic perspective this is not sufficient. There are other social, political and community factors that impact the attainment of lifelong healthy habits among students. Assessing the effect of school-based technology-supported interventions on BMI, in isolation from other influences, maybe another reason for the lack of statistically significant effect on BMI that our review found. Hence, to achieve the overall public health objective of reducing childhood obesity, then there is a need to address these factors in tandem by adopting several public health strategies at each level of the socio-ecologic model.

LIMITATIONS

This review was limited to RCT and quasi-experimental studies that examined technology-supported, behavioral interventions intended to combat the childhood obesity epidemic. It did not include interventions that aimed to modify the physical environment in ways that are conducive to the adoption of healthy practices. As these environmental interventions are making significant impacts, future studies that include the combined evaluation of behavioral programs and environmental interventions are warranted.

Our review did not evaluate the cost-effectiveness of technology-supported, behavioral interventions programs in a school setting. Though this can be a topic of further research, the use of economic tools to evaluate public health intervention programs is not always feasible.

RECOMMENDATIONS

The school-based technology-supported interventions resulted in changing unhealthy behaviors and the adoption of healthy lifestyle patterns. We recommend integrating technology-based interventions into the health education curriculum of schools. Having technology-supported health education program in schools will help students to acquire life-long healthy behaviors, habits that are in dire needed to be instilled in the youngsters to combat the growing demand of consumerism.

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REFERENCES

Abood, D. A., Black, D. R., & Coster, D. C. (2008). Evaluation of a school-based teen obesity prevention minimal intervention. Journal of Nutrition Education & Behavior, 40(3), 168-174. http://dx.doi.org/10.1016/j.jneb.2007.02.009

Anastopoulou, S., Sharples, M., Ainsworth, S., Crook, C., O'Malley, C., & Wright, M. (2012). Creating personal meaning through technology-supported science inquiry learning across formal and informal settings. International Journal of Science Education, 34(2), 251-273. http://dx.doi.org/10.1080/09500693.2011.569958

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

Baños, R. M., Cebolla, A., Oliver, E., Alcañiz, M., & Botella, C. (2013). Efficacy and acceptability of an Internet platform to improve the learning of nutritional knowledge in children: The ETIOBE mates. Health Education Research, 28(2), 234-248. http://dx.doi.org/10.1093/her/cys044

Barbee, S., & Bennett, M. (2016). Wearable technology and childhood fitness: Investigating technology to enhance fitness levels of elementary students. In G. Chamblee & L. Langub (Eds.), Proceedings of Society for Information Technology & Teacher Education International Conference 2016 (pp. 1299-1304). Savannah, GA: Association for the Advancement of Computing in Education.

Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2009). Introduction to meta-analysis. Chichester, UK: Wiley.

Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2010). A basic introduction to fixed-effect and random-effects models for meta-analysis. Research Synthesis Methods, 1, 97-111. http://dx.doi.org/10.1002/jrsm.12

Brown, T., Moore, T. H., Hooper, L., Gao, Y., Zayegh, A., Ijaz, S., ... & Waters, E. (2019). Interventions for preventing obesity in children. Cochrane Database of Systematic Reviews, 7. http://dx.doi.org/10.1002/14651858.CD001871.pub4

Chen, S., Zhu, X., Kim, Y., Welk, G., & Lanningham-Foster, L. (2016). Enhancing energy balance education through physical education and self-monitoring technology. European Physical Education Review, 22(2), 137-149. http://dx.doi.org/10.1177/1356336X15588901

Cook, T. L., De Bourdeaudhuij, I., Maes, L., Haerens, L., Grammatikaki, E., Widhalm, K., & Manios, Y. (2014). Psychosocial determinants and perceived environmental barriers as mediators of the effectiveness of a web-based tailored intervention promoting physical activity in adolescents: The HELENA Activ-O-Meter. Journal of Physical Activity & Health, 11(4), 741-751. http://dx.doi.org/10.1123/jpah.2012-0120

Cullen, K. W., Watson, K., Baranowski, T., Baranowski, J. H., & Zakeri, I. (2005). Squire's Quest: Intervention changes occurred at lunch and snack meals. Appetite, 45(2), 148-151. http://dx.doi.org/10.1016/j.appet.2005.04.001

Di Angelantonio, E., Bhupathiraju, S. N., Wormser, D., Gao, P., Kaptoge, S., de Gonzalez, A. B., ... & Lewington, S. (2016). Body-mass index and all-cause mortality: Individual-participant-data meta-analysis of 239 prospective studies in four continents. The Lancet, 388(10046), 776-786. http://dx.doi.org/10.1016/S0140-6736(16)30175-1

Eagly, A. H., & Chaiken, S. (1993). The psychology of attitudes. Fort Worth, TX: Harcourt, Brace, Jovanovich.

Edwards, D., Noyes, J., Lowes, L., Spencer, L. H., & Gregory, J. W. (2014). An ongoing struggle: A mixed-method systematic review of interventions, barriers and facilitators to achieving optimal self-care by children and young people with type 1 diabetes in educational settings. BMC pediatrics, 14(1), 228. http://dx.doi.org/10.1186/1471-2431-14-228

Ennis, C. D. (2010). On their own: Preparing students for a lifetime. Journal of Physical Education, Recreation & Dance, 81(5), 17-22. http://dx.doi.org/10.1080/07303084.2010.10598475

Fisher, J. D., Fisher, W. A., & Shuper, P. A. (2009). The information-motivation-behavioral skills model of HIV preventive behavior. In R. J. DiClemente, R. A. Crosby, & M. C. Kegler (Eds.), Emerging theories in health promotion practice and research (2nd ed., pp.21-63). John Wiley & Sons.

Glass, G. V., McGaw, B., & Smith, M. L. (1981). Meta-analysis in social research. Beverly Hills, CA: Sage.

Goldfine, B. D., & Nahas, M. V. (1993). Incorporating health-fitness concepts in secondary physical education curricula. Journal of school health, 63(3), 142-146. http://dx.doi.org/10.1111/j.1746-1561.1993.tb06103.x

González, C. S., Gómez, N., Navarro, V., Cairós, M., Quirce, C., Toledo, P., & Marrero-Gordillo, N. (2016). Learning healthy lifestyles through active videogames, motor games and the gamification of educational activities. Computers in Human Behavior, 55, 529-551. http://dx.doi.org/10.1016/j.chb.2015.08.052

González-Cutre, D., Ferriz, R., Beltrán-Carrillo, V. J., Andrés-Fabra, J. A., Montero-Carretero, C., Cervelló, E., & Moreno-Murcia, J. A. (2014). Promotion of autonomy for participation in physical activity: A study based on the trans-contextual model of motivation. Educational Psychology, 34(3), 367-384. http://dx.doi.org/10.1080/01443410.2013.817325

Guerra, P. H., Nobre, M. R. C., Silveira, J. A. C. D., & Taddei, J. A. D. A. C. (2013). The effect of school-based physical activity interventions on body mass index: A meta-analysis of randomized trials. Clinics, 68(9), 1263-1273. http://dx.doi.org/10.6061/clinics/2013(09)14

Hammond, J., Jones, V., Hill, E. L., Green, D., & Male, I. (2014). An investigation of the impact of regular use of the Wii Fit to improve motor and psychosocial outcomes in children with movement difficulties: A pilot study. Child: Care, Health & Development, 40(2), 165-175. http://dx.doi.org/10.1111/cch.12029

Hieftje, K., Edelman, E. J., Camenga, D. R., & Fiellin, L. E. (2013). Electronic media-based health interventions promoting behavior change in youth: a systematic review. JAMA Pediatrics, 167(6), 574-580. http://dx.doi.org/10.1001/jamapediatrics.2013.1095

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. British Medical Journal, 327(7414), 557-560. http://dx.doi.org/10.1136/bmj.327.7414.557

Hedges, L. V., & Olkin, I. (1985). Statistical methods for meta-analysis. Orlando, FL: Academic Press.

Hedges, L. V., Shymansky, J. A., & Woodworth, G. (1989). A practical guide to modern methods of meta-analysis. Washington, DC: National Science Teachers Association.

Hodges, M. G., Kulinna, P. H., van der Mars, H., & Lee, C. (2016). Knowledge in action: Fitness lesson segments that teach health-related fitness in elementary physical education. Journal of Teaching in Physical Education, 35(1), 16-26. http://dx.doi.org/10.1123/jtpe.2014-0102

Hung, C.-M., Chiu, C.-H., Chen, Y.-T., Su, M.-J., & Chen, H.-S. (2009). Effectiveness of game-based learning of a national health e-learning network for nutrition education in elementary school. Paper presented at the 11th International Conference on e-Health Networking, Applications and Services, Sydney, Australia. Retrieved from http://ieeexplore.ieee.org/abstract/document/5406187/

Katz, D. L. (2009). School-based interventions for health promotion and weight control: Not just waiting on the world to change. Annual Review of Public Health, 30, 253-272. http://dx.doi.org/10.1146/annurev.publhealth.031308.100307

Korat, O., & Shamir, A. (2008). The educational electronic book as a tool for supporting children’s emergent literacy in low versus middle SES groups. Computers & Education, 50, 110-124. http://dx.doi.org/10.1016/j.compedu.2006.04.002

Kriemler, S., Zahner, L., Schindler, C., Meyer, U., Hartmann, T., Hebestreit, H., ... & Puder, J. J. (2010). Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: cluster randomised controlled trial. BMJ, 340, c785. http://dx.doi.org/10.1136/bmj.c785

Lau, E. Y., Lau, P. W. C., Chung, P.-K., Ransdell, L. B., & Archer, E. (2012). Evaluation of an Internet-short message service-based intervention for promoting physical activity in Hong Kong Chinese adolescent school children: A pilot study. Cyberpsychology, Behavior, and Social Networking, 15(8), 425-434. http://dx.doi.org/10.1089/cyber.2012.0161

Leme, A. C. B., Lubans, D. R., Guerra, P. H., Dewar, D., Toassa, E. C., & Philippi, S. T. (2016). Preventing obesity among Brazilian adolescent girls: Six-month outcomes of the Healthy Habits, Healthy Girls-Brazil school-based randomized controlled trial. Preventive Medicine, 86, 77-83. http://dx.doi.org/10.1016/j.ypmed.2016.01.020

Liu, Z., Xu, H. M., Wen, L. M., Peng, Y. Z., Lin, L. Z., Zhou, S., ... & Wang, H. J. (2019). A systematic review and meta-analysis of the overall effects of school-based obesity prevention interventions and effect differences by intervention components. International Journal of Behavioral Nutrition and Physical Activity, 16(1), 95. http://dx.doi.org/10.1186/s12966-019-0848-8

Lubans, D. R., Smith, J. J., Skinner, G., & Morgan, P. J. (2014). Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. Frontiers in Public Health, 2, 42. http://dx.doi.org/10.3389/fpubh.2014.00042

Menêses Hardman, C., Gomes de Barros, M. V., da Silva Lopes, A., Antunes Lima, R., Bezerra, J., & Vinicius Nahas, M. (2014). Effectiveness of a school-based intervention regarding screen time in high school students. Brazilian Journal of Kineanthropometry & Human Performance, 16, 26-35. http://dx.doi.org/10.5007/1980-0037.2014v16s1p25

Mokdad, A. H., Marks, J. S., Stroup, D. F., & Gerberding, J. L. (2004). Actual causes of death in the United States, 2000. Journal of the American Medical Association, 291(10), 1238-1245. http://dx.doi.org/10.1001/jama.291.10.1238

Monyeki, M. A., Moss, S. J., Kemper, H. C., & Twisk, J. W. (2018). Self-reported physical activity is not a valid method for measuring physical activity in 15-year-old South African boys and girls. Children, 5(6), 71. http://dx.doi.org/10.3390/children5060071

Müller, A.M., Alley, S., Schoeppe, S., & Vandelanotte, C. (2016). The effectiveness of e-& mHealth interventions to promote physical activity and healthy diets in developing countries: A systematic review. International Journal of Behavioral Nutrition and Physical Activity, 13, 109. https://doi.org/10.1186/s12966-016-0434-2

Palmer, S., Graham, G., & Elliott, E. (2005). Effects of a web-based health program on fifth grade children's physical activity knowledge, attitudes and behavior. Journal of Health Education, 36(2), 86-93. http://dx.doi.org/10.1080/19325037.2005.10608164

Papastergiou, M. (2009). Exploring the potential of computer and video games for health and physical education: A literature review. Computers & Education, 53(3), 603-622. http://dx.doi.org/10.1016/j.compedu.2009.04.001

Pryor, C. (2014). The effect of an iPad application on the quality of lunches brought from home by middle school children (Master's thesis). Available from ProQuest Dissertations & Theses Global database. (UMI 1555683)

Räihä, T., Tossavainen, K., Turunen, H., & Enkenberg, J. (2004). A web-based learning environment in nutrition health education. In L. C. C. McLoughlin (Ed.), Proceedings of EdMedia: World Conference on Educational Media and Technology 2004 (pp. 4020-4027). Lugano, Switzerland: Association for the Advancement of Computing in Education (AACE).

Sharma, S. V., Shegog, R., Chow, J., Finley, C., Pomeroy, M., Smith, C., & Hoelscher, D. M. (2015). Effects of the quest to lava mountain computer game on dietary and physical activity behaviors of elementary school children: A pilot group-randomized controlled trial. Journal of the Academy of Nutrition & Dietetics, 115(8), 1260-1271. http://dx.doi.org/10.1016/j.jand.2015.02.022

Shen, M., Hu, M., & Sun, Z. (2015). Assessment of school-based quasi-experimental nutrition and food safety health education for primary school students in two poverty-stricken counties of West China. PLoS ONE, 10(12). http://dx.doi.org/10.1371/journal.pone.0145090

Schöpfel, J., & Farace, D. (2010). Grey literature in library and information studies. Boston, MA: De Gruyter Saur.

Smith, J. J., Morgan, P. J., Plotnikoff, R. C., Dally, K. A., Salmon, J., Okely, A. D., . . . Lubans, D. R. (2014). Rationale and study protocol for the 'active teen leaders avoiding screen-time' (ATLAS) group randomized controlled trial: an obesity prevention intervention for adolescent boys from schools in low-income communities. Contemporary Clinical Trials, 37(1), 106-119. http://dx.doi.org/10.1016/j.cct.2013.11.008

Struempler, B., Parmer, S. M., & Funderburk, K. (2016). Use of blended learning to improve nutrition knowledge in third-graders. Journal of Nutrition Education & Behavior, 48(7), 510-511.e511. http://dx.doi.org/10.1016/j.jneb.2016.04.401

Summerbell, C. D., Waters, E., Edmunds, L., Kelly, S. A., Brown, T., & Campbell, K. J. (2005). Interventions for preventing obesity in children. Cochrane database of systematic reviews, 3. http://dx.doi.org/10.1002/14651858.CD001871.pub2

Van Dam, R. M., Li, T., Spiegelman, D., Franco, O. H., & Hu, F. B. (2008). Combined impact of lifestyle factors on mortality: Prospective cohort study in US women. British Medical Journal, 337, a1440. http://dx.doi.org/10.1136/bmj.a1440

Vio, F., Salinas, J., Montenegro, E., González, C. G., & Lera, L. (2014). Impact of a nutrition education intervention in teachers, preschool and basic school-age children in Valparaiso region in Chile. Nutricion hospitalaria, 29(6), 1298-1304. http://dx.doi.org/10.3305/nh.2014.29.6.7409

Wan, T. T., Rav-Marathe, K., & Marathe, S. (2016). A systematic review of KAP-O framework for diabetes. Medical Research Archives, 3(9). Retrieved from https://journals.ke-i.org/index.php/mra/article/view/483

Waters, E., de Silva-Sanigorski, A., Hall, B.J., Brown, T., Campell, K.J., Gao, Y., Armstrong, R., Prosser, L., Summerbell, C.D. (2011). Interventions for preventing obesity in children. Cochrane database of systematic reviews, 12. http://dx.doi.org/10.1002/14651858.CD001871.pub3

Williams, O., DeSorbo, A., Sawyer, V., Apakama, D., Shaffer, M., Gerin, W., & Noble, J. (2016). Hip hop HEALS: Pilot study of a culturally targeted calorie label intervention to improve food purchases of children. Health Education & Behavior, 43(1), 68-75. http://dx.doi.org/10.1177/1090198115596733

World Health Organization (WHO). (2008). Advocacy, communication and social mobilization for TB control: A guide to developing knowledge, attitude and practice surveys. Retrieved from https://apps.who.int/iris/handle/10665/43790

Wyatt, T. H., & Hauenstein, E. (2008). Enhancing children's health through digital story. Computers, Informatics, Nursing, 26(3), 142-148. http://dx.doi.org/10.1097/01.NCN.0000304779.49941.44

United Nations Children's Fund (UNICEF). (2017). A study of knowledge, attitude and practice (KAP) before and after implementation of parental education programme in 3 districts of Nepal. Retrieved from https://www.unicef.org/nepal/reports/study-knowledge-attitude-and-practice-and-after-implementation-parental-education

Xu, F., Wang, X., Xiang, D., Wang, Z., Ye, Q., & Ware, R. S. (2017). Awareness of knowledge and practice regarding physical activity: A population-based prospective, observational study among students in Nanjing, China. PloS One, 12(6). http://dx.doi.org/10.1371/journal.pone.0179518

Yang, Y.-T. C., Wang, C.-J., Tsai, M.-F., & Wang, J.-S. (2015). Technology-enhanced game-based team learning for improving intake of food groups and nutritional elements. Computers & Education, 88, 143-159. http://dx.doi.org/10.1016/j.compedu.2015.04.008

Zach, S., Raviv, T., & Meckel, Y. (2016). Using information communication technologies (ICTs) for motivating female adolescents to exercise/run in their leisure time. Computers in Human Behavior, 60, 593-601. http://dx.doi.org/10.1016/j.chb.2016.02.096

Zhu, X., & Dragon, L. A. (2016). Physical activity and situational interest in mobile technology integrated physical education: A preliminary study. Acta Gymnica, 46(2), 59-67. http://dx.doi.org/10.5507/ag.2016.010