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Future directions in physical activity intervention research: expanding our focus to sedentary behaviors, technology, and dissemination

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Abstract

Despite the increased health risks of a sedentary lifestyle, only 49 % of American adults participate in physical activity (PA) at the recommended levels. In an effort to move the PA field forward, we briefly review three emerging areas of PA intervention research. First, new intervention research has focused on not only increasing PA but also on decreasing sedentary behavior. Researchers should utilize randomized controlled trials, common terminology, investigate which behaviors should replace sedentary behaviors, evaluate long-term outcomes, and focus across the lifespan. Second, technology has contributed to an increase in sedentary behavior but has also led to innovative PA interventions. PA technology research should focus on large randomized trials with evidence-based components, explore social networking and innovative apps, improve PA monitoring, consider the lifespan, and be grounded in theory. Finally, in an effort to maximize public health impact, dissemination efforts should address the RE-AIM model, health disparities, and intervention costs.

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Compliance with ethical standards

Conflict of interest Beth A. Lewis, Melissa A. Napolitano, Matthew P. Buman, David M. Williams and Claudio R. Nigg declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Keywords

Physical activity; Sedentary behavior; Dissemination; Intervention; Technology

Rationale and purpose

Physical inactivity is related to numerous health problems including increased risk of heart disease, hypertension, and stroke (AHA, 2015). However, based on self-report, only 49.2 % of American adults engage in physical activity at the recommended levels (CDC, 2015), and 25 % of Americans are completely sedentary (defined as engaging in no leisure-time physical activity; CDC, 2014). Objective data obtained via an accelerometer (i.e., a small device that is worn and objectively measures activity) indicates that Americans perform just 5.7–10.3 min/day of moderate-to-vigorous physical activity in bouts of 10 min or longer (as recommended for a public health benefit; PA Guidelines Advisory Committee, 2008; Troiano et al., 2008). Per day averages were calculated based on four to 7 days of data (depending on how many valid days of data were available for each participant). It is an exciting time for physical activity research given evolving technology for intervening upon PA, a new focus on novel behavioral targets (e.g., sedentary behavior), and increased attention on scaling evidence-based interventions for maximal public health impact.

The purpose of this paper was to explore emerging areas in physical activity intervention research based on this writing team's consensus supported by input from members of the Society of Behavioral Medicine's Physical Activity Special Interest Group. The emerging themes identified included: (1) Interventions targeting sedentary behavior; (2) examining the efficacy of technology-based physical activity interventions; and (3) dissemination of physical activity interventions. First, research examining the efficacy of interventions specifically targeting sedentary behavior has increased in recent years (Neuhaus et al., 2014a; Prince et al., 2014). This research indicates that replacing sedentary activities with moderate-to-vigorous physical activity (MVPA) has a profound impact on health outcomes. However, additional benefits can be conferred by replacing sedentary time with less intense activity including standing (Healy et al., 2015) and light-intensity physical activity (Buman et al., 2013). Sedentary behavior has thus emerged as a novel and independent behavioral target for interventions.

The second line of research identified was the efficacy of technology-based physical activity interventions (Bort-Roig et al., 2014; Fanning et al., 2012). As technology continues to advance, it is becoming easier to integrate new and emerging platforms, software, and devices into physical activity interventions. As consumers increase their use of technology, it is important for researchers to better understand how technology can be used to promote physical activity, and how best to partner with technology companies to integrate "off the shelf" products with theory-based interventions. Finally, how best to expand and evaluate the dissemination of efficacious physical activity interventions to real world settings is an emerging area that was explored. Dissemination is essential for reaching the large number of sedentary adults and youth and maximizing the public health impact of our efforts. In summary, the overall goal of this paper was to critically evaluate the intervention studies conducted in these three areas and outline specific recommendations for future research.

Interventions targeting sedentary behavior

Summary and critical evaluation of current state of knowledge

Sedentary behavior is defined as, "Any waking behavior characterized by an energy expenditure less than 1.5 METs while in a sitting or reclining posture (e.g., watching television, driving, working on a computer; Sedentary Behaviour Research Network, 2012). As noted, sedentary behavior is related to several health conditions including increased risk of cardiovascular disease, cancer, diabetes, and weight gain (Thorp et al., 2011; Wilmot et al., 2012) even when MVPA is controlled (Thorp et al., 2011). It is important to note that sedentary behavior is not or only slightly negatively correlated with MVPA (Buckworth & Nigg, 2004), indicating the relative independence of the two behaviors. Sedentary behavior also increases the risk of premature mortality by 49 % (Wilmot et al., 2012). Results also indicate that sedentary behavior is related to a 73 % increased risk of metabolic syndrome, regardless of physical activity level (Edwardson et al., 2012). Despite these negative health consequences, Americans sit on average 7.5 h per day as measured by an accelerometer (Matthews et al., 2008). Working adults spend 66 % of the workday sitting (Ryan et al., 2011). One study found that two-thirds of sitting events last longer than 20 min at a time (Ryan et al., 2011). Intervention research on sedentary behavior is especially challenging due to a lack of consensus regarding recommended targets and guidelines and limitations related to self-report and accelerometers (e.g., difficulty differentiating between standing and sitting, expensive).

Currently the US Physical Activity Guidelines for Americans explicitly recognize the need to "minimize the amount of time spent being sedentary for extended periods" but provide few behavioral targets to reach this goal (USDHHS, 2008). Australian and Canadian governments have issued additional and more specific guidance including limiting electronics use in youth and breaking up prolonged sitting periods in adults (Australian Government Department of Health, 2014; Canadian Society for Exercise Physiology, 2012). However, there is still a lack of international consensus regarding guidelines for sedentary behavior. A 2010 review of national guidelines found seven countries have established sedentary behavior guidelines, but only three have set quantified limits. This is likely due to the lack of data available to inform the setting of sedentary behavior guidelines specific to each country. The majority of these guidelines focus exclusively on children and young people, and the quantified limits appear to be based solely on expert opinion (Ekelund et al., 2010). There still remains limited data on precisely how much sedentary behavior is too much and how sedentary behavior is optimally reduced and broken up.

A recent meta-analysis examined the effect of interventions on both physical activity and sedentary behavior (Prince et al., 2014). The authors concluded there was consistent support for large reductions in sedentary time as a result of interventions that focus on reducing sedentary behavior, but little evidence supporting reductions in sedentary behavior as a result of interventions targeting physical activity. This meta-analysis identified several studies that targeted older adults. One study found that older adults (n = 41) randomized to a nursedelivered intervention based on social cognitive theory reduced their sedentary time by 68 min per day (based on step counts on a pedometer and *activ*PAL) relative to the controls (Mutrie et al., 2012). In another study, older adults (n = 478) who were randomly assigned to a home-based intervention based on social cognitive theory reported 57 fewer minutes of sitting per day than the controls (Burke et al., 2013).

A recent meta-analysis examined the efficacy of active workstations on decreasing sedentary behavior in the workplace (Neuhaus et al., 2014a). Active workstations can include sit-stand desks (i.e., desks that move up and down to accommodate both sitting and standing), treadmill desks (i.e., walking on a treadmill while working at a desk), or a pedal or stepping device that is placed under the desk. Nineteen field-based studies and 19 laboratory trials were identified in this meta-analysis. Results indicated that active workstations led to a 77-min reduction of sedentary time during an 8-h workday. The active workstations also resulted in a smaller waist circumference and improved psychological well-being. There were minimal reductions in work performance and little improvement in health-related outcomes (e.g., weight, musculoskeletal symptoms, fatigue, biomarkers) as a result of the active workstations, although most of the studies were not powered to detect the effect of active workstations on work productivity or health outcomes. One study did find that participants reported feeling more energetic, relaxed, and calm when using the sit-stand workstations rather than the traditional workstations (Dutta et al., 2014). Several of the studies examining the efficacy of sit-stand workstations are limited by non-randomized designs and short-term interventions (Alkhajah et al., 2012; Dutta et al., 2014). One of the few randomized trials examining sit-stand workstations found that participants (n = 47) randomized to a sit-stand condition for 8 weeks reported an 80-min decrease in sitting time (assessed via an ecological momentary assessment diary), a 73-min increase in standing time, and a decrease in cholesterol levels relative to a control (Graves et al., 2015).

The efficacy of technology-based interventions for reducing sedentary time have also been evaluated (Bond et al., 2014; King et al., 2013; Dantzig et al., 2013). For example, King et al. (2013) found that adults ages 45 and older (n = 80) who received one of three mobile apps decreased their sedentary time (defined as self-reported sedentary activities such as reading, television watching, and working at a desk) over 8 weeks. One limitation was that this study did not have a true control group and subjective measures of activity time were used. Another study included three different apps that resembled a fuel gauge and reminded participants (n = 30), who were overweight or obese, when it was time to take a break from sitting (Bond et al., 2014). Although there were no differences between the three conditions, all groups decreased their sedentary time (defined as activity that was less than light intensity based on objective monitoring) over the 7 days. A strength of this study is that participants wore a mini armband (i.e., wireless multi-sensor monitor that was worn on the tricep and estimated energy expenditure and intensity) to objectively measure sedentary behavior.

Particularly relevant to behavioral scientists, few sedentary behavioral interventions have applied existing evidence-based behavioral strategies to address sedentary behavior. Given the relative independence of sedentary behavior from physical activity, it is unclear if strategies for increasing physical activity are directly applicable to sedentary behaviors (e.g., goal setting, reinforcement). More evidence is needed regarding efficacious theory-based behavioral strategies for reducing sedentary behavior. As technology continues to evolve and becomes even more important in daily life, it is imperative for researchers to design studies that will lead to a better understanding of the role technology can play on reducing both sedentary behavior and increasing physical activity.

Research recommendations/future directions

The sedentary behavior research area is a relatively new area of research, which has received increased attention in recent years (Neuhaus et al., 2014a; Prince et al., 2014). For example, the National Heart, Lung, and Blood Institute (NHLBI) and National Institute on Aging (NIA) hosted a joint workshop entitled, "Influences on Sedentary Behavior and Interventions to Reduce Sedentary Behavior (Manini et al., 2015; Rosenberg et al., 2015)." They also concluded that sedentary behavior should be considered as a distinct concept from physical activity. To follow is a discussion of specific research recommendations for sedentary behavior research which includes recommendations made by the NHLBI/NIA panel, other researchers, and the authors of this manuscript.

Large, randomized trials—Large-scale randomized controlled trials targeting sedentary behavior are needed to better understand whether behavioral interventions can produce sustained effects on sedentary time, what is meaningful in regards to sedentary time reduction, and whether these effects are robust enough to produce improvements in important health outcomes. As noted, the majority of studies examining interventions targeting sedentary behavior included small sample sizes, and many of the studies lacked randomization (Neuhaus et al., 2014a; Prince et al., 2014). Related, because many sedentary behaviors are context-specific (e.g., schools, worksites), it is often difficult or impossible to maintain independence between individuals; thus, cluster-randomized designs are likely necessary when intervening in certain contexts. Several studies examined the effect of the intervention on health outcomes, but very few were powered to detect differences on these outcomes (Neuhaus et al., 2014a). It will be important for future studies to not only include large, randomized designs but to also examine important health outcomes that are related to a sedentary lifestyle (e.g., blood glucose levels, blood pressure, biomarkers, quality of life).

Replacement behaviors—It is important for researchers to conduct studies that lead to a better understanding of what types of behaviors optimally replace sedentary behavior. Specifically, studies should specify whether sedentary behavior is being replaced by sleep, light, moderate, or vigorous intensity activities given this can have important implications for health outcomes. Buman et al. (2013) examined the effect of reallocating sedentary time on cardiovascular risk using biomarker data obtained from NHANES data. Results indicated that there was a 2–25 % improvement in risk for every 30 min shifted from sedentary behavior to MVPA and a 2–4 % improvement when reallocated to light activity. Additionally, studies that focus on decreasing sedentary time specifically in the workplace should examine if sedentary time increases or decreases outside of work (i.e., compensatory or transfer effects, for a more in depth discussion of the concepts of compensation and transfer see the Multiple Behavior Manuscript of this issue). Koepp et al. (2013) conducted a study in which participants were given treadmill desks to decrease sedentary behavior at work. Sedentary time significantly decreased from baseline to 6 and 12 months, and overall physical activity throughout the entire day increased from baseline to 6 and 12 months. These findings indicate that physical activity outside of the workday does not decrease as a result of having an active workstation.

Long-term outcomes—The meta-analysis conducted by Neuhaus et al. (2014a) found that of the 38 studies examined, only three studies examined sedentary behavior beyond the initial intervention period. Consequently, there is a need for studies to examine long-term sedentary behavior once the novelty of the intervention (e.g., sit-stand workstations, mobile apps) decreases. For example, it is unclear what the long-term compliance rates are for the sit-stand desks. It is possible that sit-stand desks could lead to discomfort as a result of postural variety (Gregory & Callaghan, 2008). Therefore, despite decreasing sedentary time, sit-stand workstations could lead to long-term musculoskeletal pain. Some studies reported negative feedback regarding the sit-stand workstations (Neuhaus et al., 2014b) and thus, the acceptability of these workstations should be further examined. For example, one study found that participants reported disadvantages to the workstations including decreased desk-space and not having the ability to adjust the distance between their eyes and the computer screen (Neuhaus et al., 2014b). However, this same study found that acceptability of the workstations was high and another study found that sit-stand desks resulted in less discomfort (Karakolis & Callaghan, 2014). Additional studies are needed to better understand the long-term effect of sedentary-reducing interventions such as sit-stand workstations.

Evaluate interventions across the lifespan—Manini et al. (2015) recommend that the acceptability, feasibility, and effectiveness of sedentary behavior interventions be evaluated across the lifespan. Full-time employment verses retirement can result in very different types of sitting behaviors throughout the day. Furthermore, according to one study adults stand on average 75 min less and sit 100 min more on workdays compared to non-workdays (McCrady & Levine, 2009). As technology continues to evolve and becomes more important across the lifespan, the role technology can play on decreasing sedentary behavior and increasing physical activity should be explored.

Use of technology to promote physical activity

Summary and critical evaluation of current state of knowledge

Technology as a health promotion tool has evolved significantly over the past 10–20 years (Lupton, 2015). However, technology has also been blamed for the significant increase in sedentary behavior over the past 50 years (Clark & Sugiyama, 2015). Video games, computers, televisions, mobile devices, and sedentary occupations have all contributed to an increase in both sedentary behavior and obesity (Church et al., 2011; Clark & Sugiyama, 2015). Technology has several advantages over more traditional face-to-face approaches; these interventions allow for continual self-monitoring and access, reduce barriers of transportation and time, increase standardization of protocols and decrease potential for forgetting, and have the potential to be portable in the case of smartphone interventions. Additionally, technology-based interventions have the potential to be more cost-effective, accessible, and convenient (Thomas & Bond, 2014; Khalysis et al., 2010; Bacigalupo et al., 2013) compared to traditional interventions.

To combat the public health problems related to technological advances, researchers have explored how to use technology as a way to enhance health and quality of life (Lupton, 2015). Physical activity in particular is one health behavior that has been the focus of several technology-based intervention research studies (Bort-Roig et al., 2014; Fanning et al., 2012; Norman et al., 2013). Earlier generations of technology used computer-based approaches (e.g., Internet) to create tailored communications to promote physical activity (Marcus et al., 2007; Hurling et al., 2007; Napolitano et al., 2003). These approaches have the potential for application to new and emerging technologies, platforms, and devices. Other studies have examined the capability of online social networks for delivering programs and interventions. For example, Cavallo et al. (2012) randomly assigned 134 young adults to receive access to a physical activity website (n = 67) or the same website supplemented with self-monitoring and enrollment in a Facebook group. While there were increases in social support and physical activity in both groups, there were no differences between the treatment arms.

As technology has evolved, more recent technology-based interventions have focused on the use of mobile phones as a strategy for motivating individuals to become physically active (Bort-Roig et al., 2014). Approximately 90 % of Americans have a mobile phone (Pew Internet, 2014a) and 64 % have a smartphone (e.g., cellular phone that performs several of the functions of a computer including accessing the Internet), compared to 35 % who owned a smartphone in 2011 (Pew Internet, 2015). As of 2014, 84 % of those earning <$30,000 a year reported having a cell phone (Pew Internet, 2014a) and 85 % of young adults own a smartphone (Pew Internet, 2015). Importantly, more than half of smartphone owners have used their phones to search for health information in the past year (Pew Internet, 2015). Given the high use of mobile and smartphones and the increasing popularity of smartwatches, this venue may be an ideal platform for the administration of physical activity interventions. For example, a review by Pratt et al. (2012) found that mobile phones in middle to upper income countries have similar effects on physical activity when compared to planned physical activity interventions in clinical and community settings.

Preliminary evidence indicates that interventions using mobile phones may increase physical activity (King et al., 2015). For example, Fanning et al. (2012) conducted a meta-analysis examining the efficacy of mobile phones for physical activity promotion. The duration of the interventions ranged from 2 to 52 weeks with an average of 14.6 weeks. This meta-analysis found that mobile phone interventions had a moderate, positive effect on physical activity; however, there were several limitations related to the studies. Only four of the seven studies identified were classified as having “good” quality methodology (quality was based on sampling, population and study description, measurement, data analysis, interpretation, and additional limitations), indicating additional research is needed.

A more recent review examining the efficacy of smart-phone technology found that a majority of studies reported an increase in physical activity (Bort-Roig et al., 2014). However, of the 13 intervention articles identified in this review, only six reported on physical activity behavior change. Five of these six studies reported steps per day rather than minutes per week of physical activity, which is problematic given steps can be inaccurate for non-walking activities. Only four of the 13 studies reported a theoretical framework that guided the intervention. Four of the studies were pre-posttest designs and only one had a control condition. Taken together, there is a strong need for theory-based large randomized controlled trials using objective physical activity measures.

A recent study reviewed the content of commercially available smartphone apps (Middelweerd et al., 2014); 41 apps were identified from iTunes and 23 from Google Play. The apps used five behavior change strategies on average (range was from 2 to 8), which is less than the eight that are reported in traditional behavioral interventions on average (Abraham & Michie, 2008). The most common types of strategies included feedback, self-monitoring, and goal setting. Other evidence-based treatment components (barriers identification, relapse prevention, role modeling, motivational interviewing, and stress management) were not used in any of the apps. Thus, there appears to be a disconnect between behavioral strategies shown to be efficacious in face-to-face studies and the implementation of these strategies in technology-delivered interventions. It is important for future investigators to combine the potential of these approaches, perhaps by integrating existing technologies into theory-based interventions for physical activity adoption and maintenance.

Recent studies have examined if “wearable” devices (i.e., electronic devices that are worn and monitor activity such as the Fitbit; Xu et al., 2015) can increase physical activity monitoring and adherence. For example, Cadmus-Bertram et al. (2015) found that the median participant wore their Fitbit for 10 or more hours per day on 95 % of the intervention days (16 week intervention) and Xu et al. (2015) showed similar (almost 100 %) rates for daily Fitbit wear over 28 consecutive days. In another study, Arigo (2015) found that participants increased their physical activity from baseline to 6 weeks after completing an online intervention that included wearable technology and social networking. The limitations of these studies is that they did not include a control group, had relatively small sample sizes, and were short in duration. Additional research examining wearable devices is needed.

In summary, there is evidence that technology-based interventions, most recently interventions using smart-phones and wearable physical activity monitors, are efficacious for increasing physical activity. However, there have been significant measurement and methodological limitations of these studies. Large scale randomized controlled trials are needed when technology-supported interventions have promising preliminary evidence, when the intervention components have been clearly defined and implemented, and there is promise for future scalability. Other high quality designs (e.g., adaptive designs, multiphase optimization designs) are recommended if researching different intensities or a different component of technologically based tailoring (see Riley et al., 2015). Specific research recommendations related to technology are summarized in more detail below.

Research recommendations/future directions

Similar to the sedentary behavior intervention literature, the examination of technology-related interventions is a somewhat new area of research and thus, there is a strong need for additional studies. King et al. (2015) recently differentiated between “me” and “we” contexts for examining technology-related interventions. The “me” domain refers to personal-level contexts and behaviors, including self-monitoring and using apps to intervene at the individual level for physical activity behavior change. The “we” domain refers to aggregated data across people and large-scale contexts. This domain is based on an environmental and population science-based perspective examining the interaction between the physical and social environmental contexts. It can include web-based tools such as Google Earth and apps that involve electronic games for outdoor walking. One example of a “we” domain is the System for Observing Play and Recreation in Communities (SOPARC), which was designed for evaluating park and recreation areas with respect to physical activity levels (McKenzie et al., 2006). This online tool is available via a mobile app and includes a protocol, mapping strategies, coding forms, and training materials. These two domains should be considered when conducting research in the technology area and implementing the recommendations below for future research.

Need for large-scale randomized trials—The examination of technology-based interventions is a relatively new area of research for physical activity promotion and there have been few large-scale randomized trials in this area. This is not surprising given the relatively emergent nature of this field of research. There is a need for large-scale randomized trials examining the efficacy of technology-based intervention on physical activity behavior. There is significant room for improvement for future studies when compared to the existing literature in this area. However, in some areas it may be necessary to first examine interventions via smaller pilot studies to establish preliminary efficacy prior to the large randomized trial.

Include evidence-based components—Khaylis et al. (2010) identified five essential components that should be incorporated into all technology-based interventions. These include: (1) Counselor feedback; (2) self-monitoring; (3) structured program; (4) individual tailoring; and (5) social support. Counselor feedback can include either adjunct face-to-face meetings or it can be electronic feedback via text messaging or emails. Self-monitoring could include wearing electronic devices that objectively monitor physical activity or documenting physical activity using online dairies. The program should be structured in that participants should be prompted via email and/or text messages to engage in the evidence-based behavior change strategies shown to be efficacious in the literature. Individually tailored refers to setting personalized goals via an app, website, email, or text message, and/or receiving messages based on the person’s current level of physical activity. Social support can include chat rooms, online meetings, message boards, and electronic bulletin boards. Each of these five components should be included in future studies when examining the efficacy of technology-based interventions.

Consider minority group status when designing interventions—In seminal articles published several years ago, Dishman (1988) and Marcus et al. (2006) both discussed the importance of considering the influence of minority group status on physical activity behavior. Despite these recommendations, few studies have examined technology-based interventions specifically designed for minority groups. However, one recent study by

Marcus et al. (2016) did find that inactive Latinas randomly assigned to a culturally competent Internet-based intervention increased their physical activity levels relative to a wellness control. There is a strong need for adequately powered trials such as the Marcus study that considers cultural competency in technology-based intervention studies. Additionally, research indicates that a majority of studies have been conducted in upper-income countries and therefore, additional studies are needed in low and middle income countries (Pratt et al., 2012).

Consistency in physical activity reporting—The heterogeneity in the reporting of physical activity makes it is difficult to compare across studies (Lewis et al., 2016). For example, there is variation regarding how objective device data is processed and wear times of the device can vary across studies. Researchers analyzing objective data should provide a detailed description of how the data was processed and include cut-point information related to how varying levels of physical activity were determined. Furthermore, studies report physical activity in total minutes, MET-minutes, activity counts, steps per day, and kilocalories. The reporting typically varies from per day to per week. There is a need for consistency in the reporting of physical activity across studies, which would allow for streamlined comparisons when evaluating the relative efficacy of varying types of technology. We recommend reporting physical activity in minutes per week as this relates to the national recommendations.

Explore the use of social networking—The use of social networking as a component of technology-based intervention should be explored further. Research indicates that 40 % of smartphone users utilize their phone for social networking (Pew Internet, 2014b). This can involve contact with other participants in the study via a study website, apps, text messages, or emails. Other individuals can provide a source of support for adopting and maintaining physical activity. However, social networking in studies can be challenging given ethical concerns such as the loss of confidentiality among participants. There is a need to convene expert panels on the issue of social networking to better understand the confidentiality and consenting issues that can occur as a result of sharing via social networking and social media platforms.

Need for innovative apps—There is a need for new and innovative apps that can be used to increase physical activity. These could include video gaming and other ways to increase the perceived enjoyment of engaging in physical activity. Segar et al. (2011) have suggested that exercise should be "rebranded" in that physical activity should be promoted for its immediate rather than its long-term effects. Physical activity has been historically promoted as a means to prevent long-term problems such as cardiovascular disease and cancer; however, research indicates that participants are more likely to adhere to physical activity if they focus on the immediate benefits of physical activity such as increased energy, improved mood, and a sense of accomplishment (Segar et al., 2011; Stevens & Bryan, 2012). Stevens and Bryan (2012) suggest that smartphone apps could be designed to monitor daily improvements in constructs related to quality of life. For example, the apps could focus on the affective benefits of physical activity and marketing these benefits through the use of these apps. The authors suggest that it will be especially important for future studies to culturally tailor the content of the apps to the needs and barriers of African-American and Latinos given the lower levels of physical activity among minority groups.

Improve physical activity monitoring—Advancements in technology have led to improved monitoring of physical activity. Specifically, devices with accelerometers can provide fairly accurate physical activity data. However, there are still problems with these devices including: (1) Low compliance; (2) many devices cannot be worn with certain activities such as swimming; (3) the large amount of computer processing space required for streaming accelerometer data; and (4) the use of proprietary algorithms and lack of complete validation. It will be important for researchers to further examine which type of objective monitor exhibits the highest compliance and accuracy in order to have consistency in the type of monitor used across the physical activity intervention studies. Of note, given the high penetration rate of smartphones and other commercially available wearable devices, it will be important for future studies to consider using the trade-offs of precision versus adherence for objective measures of physical activity behavior, and whether commercially available devices may best be used as intervention tools, outcome measures, or both.

In order to obtain timely self-report data, researchers should consider adding Ecological Momentary Assessment (EMA) to their study protocols in addition to objective monitors to obtain real time information not detected by objective measures and for situations when the device has malfunctioned or was not worn. Another area of physical activity monitoring to be explored is the use of technology to assess activity in the environment. Sensor technology and force plates in free living environments/structures (stairs, cross walks, playground structures) can record use and energy expended while someone is on a structure. For example, where stairs and escalators are side by side, the amount of energy expended for each structure can be collected before and after a stimulus control intervention implementation. The intensity of use of a playground structure can be measured by sensors evaluating the optimal distance of the structure to the school doors, or of the structure in relation to other structures to maximize energy expended. This allows researchers to quantify which structures promote more activity and which structures are more related to sedentary behavior. In summary, Troiano et al. (2012) suggested that there is not one gold standard for physical activity assessment. They recommend that when assessing physical activity, researchers should consider the purpose of the assessment, population being studied, and theoretical constructs being assessed.

Consider the lifespan—It is important to conduct studies that lead to a better understanding of how various technology-related strategies should be implemented across the lifespan. For example, research indicates that older participants view text messaging as unfavorable compared to other age groups (Nguyen et al., 2009), although this will likely change over time. Another study found that competition-based strategies were viewed negatively by adolescent girls (Toscos et al., 2008). It is also important to conduct long-term randomized trials utilizing lifespan developmental research designs (i.e., examining the influence of developmental changes over time) to better understand how technology use interacts with aging processes. For examples, researchers should examine how cognitive and motor decline over time can influence the use of technology. These research studies could be two fold in that the efficacy of the technology is tested while also studying aging (e.g., usability, mobility strengths and limitations, biopsychosocial processes). It is also important to consider challenges researchers may encounter when physical activity and technology interventions are conducted separately, that likely will compound when approaches are integrated (e.g., aging stereotypes, discrimination, technology self-efficacy, cognitive-motor decline). Even though considering the lifespan has been recommended in previous seminal articles in the field; few researchers have adequately considered lifespan in their studies as noted by Dishman (1988) and Marcus et al. (2006).

Use of theory—There is a strong need for studies that are grounded in theory (Rhodes & Nigg, 2011; Symons Downs et al., 2013). However, a recent review conducted specifically on smartphone interventions indicated that very few studies integrated behavioral change theories into their interventions (Bort-Roig et al., 2014). A promising step forward is the Michie et al. (2013) systematic approach to link specific behavior-change intervention techniques to theoretical constructs (Gainforth et al., 2015). Recent research has challenged the importance of traditional theoretical constructs such as self-efficacy (Lewis et al., 2015), suggesting that newer theoretical constructs (e.g., enjoyment, affective responses to physical activity) should be explored (Rhodes & Kates, 2015; Williams & Evans, 2014). Once theory-based behavior strategies are successfully integrated into technology-based interventions and efficacy is firmly established, the goal will be widescale dissemination to the public.

Dissemination of physical activity interventions

Summary and critical evaluation of current state of knowledge

The ultimate goal of physical activity interventions should be eventual dissemination of the intervention once an evidence base of efficacy has been established. In newer areas of research, such as smartphone interventions, dissemination may be premature in some cases. However, there are several physical activity interventions that are likely ready for dissemination, and strategies for improved dissemination should be explored.

Recently there has been an increased emphasis on disseminating evidence-based physical activity and other health interventions. For example, the National Institutes of Health (NIH) has emphasized the importance of disseminating efficacious interventions in order to make a public health impact. There are several funding and training opportunities that have been created by the NIH Office of Behavioral and Social Sciences Research (OBSSR) in order to increase dissemination and implementation research. For example, the Training Institute for Dissemination and Implementation Research in Health (TIDIRH) has held an annual conference since 2011 that focuses on dissemination and implementation research. There are currently three grant mechanisms funded by the OBBSR entitled “Dissemination and Implementation Research in Health (i.e., R01, R03, R21).” Thus, dissemination and implementation research has become a priority at the National Institutes of Health and physical activity researchers should respond to this priority.

The RE-AIM model is a common model used in dissemination research and is designed to measure the public health impact of a particular intervention or program (Glasgow et al., 1999). This model consists of five dimensions including reach, efficacy, adoption, implementation, maintenance. Reach refers to the percentage of individuals who access the program relative to the number of individuals who could have accessed the program. Reach also includes how representative the sample is among those who accessed the program compared to the overall sample who could have accessed the program. Efficacy refers to the positive and negative consequences of a program relative to a control condition; behavioral, quality of life, and participant satisfaction variables should all be assessed. Adoption refers to the representativeness of the particular setting (e.g., worksite, community) that implements the program and the proportion of targeted settings that were reached. Implementation refers to the extent to which the program was implemented as intended in a real-world setting. Program effectiveness is thought to be an interaction between efficacy and implementation. Finally, maintenance refers to continuing to deliver the program in the organizational and/or community setting over the long-term. Examples of how these principles have been implemented within physical activity dissemination studies are summarized below.

Folta et al. (2015) conducted a national dissemination of the 12-week Strong Women-Healthy Hearts program using the RE-AIM framework. This program was designed to improve CVD risk factors, including physical activity, among midlife and older women who were sedentary and overweight or obese. The program had been shown to be efficacious in a previous trial (Folta et al., 2009). Half of the 1-h sessions consisted of either walking or exercising to an aerobics dance video and the other half focused on diet and weight control. To implement the program, health educators received program delivery training at the National Extension Association of Family and Consumer Sciences (NEAFCS) annual meeting. Results indicated that the program reached 0.15 % of the total targeted population. The adoption rate was 48 %, which was defined as the number of trained extension educators who conducted the program. Regarding maintenance, 27 % of the leaders conducted another session within 1 year of the first study. This study made a significant contribution to the literature by being one of the few physical activity intervention studies that thoroughly examined the RE-AIM components. Whether these levels attained are meaningful or large will become clear as more dissemination efforts are documented.

In another example, Nigg et al. (2012) disseminated a physical activity and nutrition program for children. The program, called “Fun 5,” was integrated in the after-school setting. The goal was for the students to engage in physical activity three times per week for at least 30 min each session. Regarding reach, the percentage of schools implementing Fun 5 increased by 52 % from year 1 to year 5 to a total of 164 sites (90 % of all sites), which was an increase of 14,061 students. The specific 5-year reach goals (80 % of all elementary after school sites) of the study were met in year 3. Effectiveness was evidenced by an increase in observed and self-reported physical activity from year 1 to year 4. Regarding adoption, implementation indicators were high (>4/5) for every subsequent year for the new sites coming on board. Maintenance was confirmed by implementation indicators remaining high (>4/5) for all continuing sites. Physical activity participation at least three times per week stayed consistently high during the 4 years of dissemination. This dissemination study was delivered in a school-setting where the target audience was clearly defined. It is important to better understand barriers that affect dissemination in other types of community-based settings.

Researchers have argued that the reliance on trained research staff to deliver the interventions significantly limits dissemination of physical activity interventions (Buman et al., 2011). These staff members can meaningfully increase the cost of an intervention and may be focused on gathering data or following a protocol, rather than on optimal treatment delivery. Therefore, studies have examined physical activity interventions delivered by non-research staff—specifically peer volunteers. Peer volunteers may enhance self-efficacy among participants by providing vicarious experiences from someone who is comparable in age, life experience, and background (Buman et al., 2011). These types of interventions have the potential to make a significant public health impact, given they may be less costly than traditional interventions with trained professionals (Castro et al., 2011; Martin Ginis et al., 2013).

Buman et al. (2011) randomized older adults to either a 16-week group-based program led by peer volunteers (based on self-determination and social cognitive theories) or a standard community intervention (two educational sessions, access to an exercise facility, and pedometers). Both groups significantly increased their physical activity and cardiorespiratory fitness from baseline to 16 weeks, and the intervention group was more likely to maintain their activity at the 18 month follow-up than the standard condition. One limitation is that the groups differed regarding intervention content and therefore, the efficacy related to the peer volunteers is unknown. In another peer volunteer study, results indicated that adults ages 50 and older who were randomly assigned to either a telephone-based intervention led by professional staff or the same intervention led by peers increased their physical activity level at 6 and 12 months relative to an attention control condition (Castro et al., 2011). Both physical activity interventions were similar regarding the quality of the intervention delivered, indicating that same-aged peers may be a viable alternative to trained professional staff both in terms of the intervention fidelity and program efficacy.

Although dissemination findings are promising, there are significant challenges in the dissemination of effective PA interventions. First, there is a need for consistent outcome measures to allow for comparisons between the dissemination and efficacy trials. Second, it is unclear which mechanism of dissemination (e.g., smartphone, interactive voice systems, Internet) is most appropriate for which population. For example, it is possible that age may influence preference for the various modalities. Finally, it is important to have consistent documentation of implementation, adoption, and maintenance. In the following section we outline specific recommendations for future work in physical activity dissemination research.

Research recommendations/future directions

There is a significant gap between what we know from a research perspective and what is being delivered in community and practice settings (OBSSR, 2015). Researchers recommend that the RE-AIM model or other dissemination focused models be used to guide dissemination research; however, these models at times have not been used or have been used incorrectly in a majority of studies. For example, research indicates that grant proposals are not doing an adequate job of addressing the RE-AIM model. Kessler et al. (2012) reviewed 42 dissemination and implementation grant applications submitted to the National Institute of Health that proposed using the RE-AIM model. This study found that <10 % included thorough measures of all RE-AIM components. Regarding published studies, Antikainen and Ellis (2011) conducted a study reviewing the external validity of 57 theory-based physical activity intervention trials based on the RE-AIM framework. These articles were more likely to report on issues related to internal than external validity. They were also more likely to report on issues related to individuals rather than an organization. A majority of studies utilized healthy, motivated participants, which reduced the generalizability of these studies. This review study outlines several recommendations regarding future physical activity research using the RE-AIM model. These and other recommendations are outlined in more detail below.

Reach—There is frequently confusion regarding how to correctly calculate reach (Kessler et al., 2012). As mentioned previously, reach is calculated by the number of participants enrolled in the program by the number of participants who received the message regarding the program. For example, if an email announcing the program was sent to 500 potential participants and 100 individuals responded but only 25 enrolled, the reach would be 5 %, not 20 %. Future studies should calculate reach based on the total number enrolled.

Based on the Antikainen and Ellis (2011) review, general physical activity intervention studies were less likely to report on the total population who were reached than school-based programs (reach was reported for 20.4 % of the general physical activity studies and 59.3 % for the school-based studies). This is not surprising given it is easier to identify the target audience in a school setting versus the general population. However, future studies should specifically identify the community from which the participants are recruited and report on the percentage reached by the intervention. Several studies use “reactive recruiting” in which participants respond to a study advertisement and therefore, researchers are unable to determine how many individuals the advertisement has reached. This has become even more problematic with online advertising where the recruitment advertisement could appear to individuals outside the targeted community. Using technology such as electronic medical records (EMR) for recruitment purposes could be helpful in identifying the exact number of participants in the targeted population.

According to the Antikainen and Ellis (2011) review, only one of the 57 studies reviewed reported on how representative the study sample was in comparison to the target population. It will be important for future studies to report the demographics of their participants and to be designed so that comparisons can be made to the target population. It would be problematic for an intervention to only reach individuals with certain demographic characteristics. For example, a physical activity intervention reaching Caucasians but not African-Americans would bias dissemination of the intervention. Finally, future studies should carefully consider the number of exclusion criteria used for the study (Antikainen & Ellis, 2011). The study becomes less likely to generalize to real world settings as the number of exclusion criteria increases.

Efficacy—As stated earlier, efficacy refers to the positive and negative consequences of a program relative to a control condition; behavioral, quality of life, and participant satisfaction variables should all be assessed. To determine if a study is efficacious, comparisons should be made across studies for physical activity behavior. However, similar to the technology-based trials, there is significant variability in the reporting of physical activity across the trials. The physical activity reporting can include physical activity minutes, kilocalories, fitness testing, and steps. Furthermore, the timeframe can vary from per day to per week. There is a need for consistency in physical activity reporting to allow for comparisons across studies. Uniform reporting would allow for a better evaluation of physical activity outcomes when programs are disseminated to real world settings. Objective assessment of physical activity may not be feasible in real-world settings; however, the units of physical activity reported could still be consistent between the original efficacy trials and dissemination trials. This is especially challenging with the use of streaming accelerometer data. Researchers should consider reporting physical activity in minutes per week because this unit of measurement most closely aligns with the national physical activity guidelines and translates best to real world settings using physical activity questionnaires and interviews.

Adoption—The adoption component of the RE-AIM model is the least reported dimension in physical activity dissemination research (Antikainen & Ellis, 2011). The setting in which the program is delivered should be thoroughly explained. Ideally, studies should calculate the participation rate of the volunteers by dividing the number of volunteers who participate in delivering the program by the number of volunteers who were invited (Blackman et al., 2013). Studies often use settings that are of convenience (e.g., university settings) and therefore, adoption cannot be tested in these interventions. Future studies should implement studies in real world settings such as physician offices, workplaces, schools, and community centers (Antikainen & Ellis, 2011).

Implementation—Approximately one-third of physical activity dissemination studies report on process information (Antikainen & Ellis, 2011). Intervention studies should report on fidelity to both the intervention protocol and its related theory (Nigg & Paxton, 2008). In a majority of studies, treatment fidelity information was not included perhaps due to not collecting the fidelity information or lack of journal space. Future studies should involve protocols that include process evaluations, which could include peer observations (i.e., volunteers observing each other's delivery of the program), audio or video recordings of sessions (i.e., supervisors listening to audio or video session recordings and providing feedback to the volunteers), and researchers interviewing or administering questionnaires to the volunteers to assess their understanding of the program.

Maintenance—Long-term maintenance of the physical activity programs are reported in about 25 % of the dissemination studies (Antikainen & Ellis, 2011). For future studies, researchers should systematically define what is considered maintenance and track the long-term maintenance of their program. For example, the Strong Women-Healthy Heart program tested maintenance by documenting if their program was implemented again in the next

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year. Even though this was a relatively short-term monitoring of maintenance, this study did operationally define maintenance and track the maintenance over time (Folta et al., 2015).

Kessler et al. (2012) make general recommendations that research proposals address all five criteria when implementing the RE-AIM framework. If only two or three are used, a justification should be included. They also recommend including a brief table summarizing definitions that are specific to their study for each of the RE-AIM components. Kessler et al. (2012) also recommend evaluating health disparities, assessing unforeseen consequences (both negative and positive), calculating costs of the program, and employing mixed methods approaches whenever possible. Future studies should consider other frameworks and models as guiding frameworks integrating research findings into practice. For example, the Practical, Robust Implementation and Sustainability Model (PRISM) is an alternate framework that describes key elements to assess when considering implementation outside the context of a research study (Feldstein & Glasgow, 2008). This framework takes into consideration the: (1) Intervention from an organizational perspective; (2) intervention from a patient perspective; (3) external environment; and (4) implementation and sustainability infrastructure.

Reaching the underserved—The National Physical Activity Plan includes several suggestions regarding how to increase the reach of physical activity interventions to underserved individuals (APHA, 2016). Healthcare strategies include ensuring that under-served groups have equal or better access to physical activity interventions delivered in a clinical setting when compared to general patients. Additionally, local, state, and national funding should be provided to increase physical activity opportunities in schools and preschools for underserved individuals. Other physical activity promotion strategies include increasing active transportation, improving land use infrastructure, creating physical activity facilities, and creating safe neighborhoods to promote physical activity among underserved individuals.

Conclusions

The purpose of this paper was to summarize the literature and provide recommendations for three emerging areas of physical activity intervention research. These areas included interventions targeting sedentary behavior, technology-based physical activity interventions, and the dissemination of efficacious physical activity interventions. Research indicates that interventions are effective for reducing sedentary time; however, limitations of these studies have included small sample sizes, a lack of randomization, short-term intervention, lack of racial/ethnic diversity, and subjective measures of physical activity in some studies. Future studies should use common terminology, explore optimal replacement behaviors for sedentary behaviors, examine long-term outcomes, include large randomized trials, and consider the lifespan. Because a majority of these studies have been conducted in the workplace, other settings should be explored.

There is growing evidence that technology-based interventions, such as smartphone interventions, are effective for increasing physical activity. However, these studies have significant measurement and methodological limitations. Large-scale, randomized studies that include long-term follow-up are needed to better understand the role technology can play in physical activity promotion. Specifically, future studies should include evidence-based components, have consistency in physical activity reporting, explore the use of social networking, examine innovative apps, improve physical activity monitoring, consider the lifespan, and utilize a theoretical framework. Additionally, researchers have not adequately addressed recommendations that were proposed decades ago (e.g., Dishman, 1988; Marcus et al., 2006) such as considering the lifespan and minority status. These factors should also be considered in future studies.

Finally, based on our review of the literature, there are very few evidence-based physical activity interventions that have been disseminated and evaluated using the recommended RE-AIM model. Public health impact is dependent on the extent to which efficacious physical activity interventions are disseminated with fidelity into real world settings, maintained, and institutionalized. However, researchers should carefully consider the efficacy of the intervention prior to dissemination. For example, smartphone physical activity interventions are relatively new and lack rigorous studies and therefore, may not be ready for dissemination. In conclusion, we would like to leave the readers with one overall important question that should be considered in all physical activity intervention research. What is the point of conducting behavioral intervention trials if there are no eventual plans for dissemination? To make a significant public health impact, researchers need to step up their efforts to improve the dissemination of physical activity programs, and consider eventual dissemination in all stages of the research process. One problem is physical activity intervention researchers may not be familiar with how to conduct dissemination research. Therefore, it will be important for these researchers to collaborate with dissemination experts once efficacy has been established and the next step towards dissemination is warranted.

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