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Physical Activity Intervention Studies: What We Know and What We Need to Know: A Scientific Statement From the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity); Council on Cardiovascular Disease in the Young; and the Interdisciplinary Working Group on Quality of Care and Outcomes Research

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AHA Scientific Statement

Physical Activity Intervention Studies

What We Know and What We Need to Know

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***Abstract*—**In this review, our first purpose is to provide an overview of existing physical activity intervention research, focusing on subpopulations and intervention modalities. Our reviews within each area are not exhaustive or quantitative, as each area has been reviewed in more depth in numerous other reports. Instead, our goal is to provide a single document that provides a qualitative overview of intervention research that emphasizes selected topics of particular importance for improving the population-wide impact of interventions. Therefore, in synthesizing this vast literature, we begin with existing reviews of physical activity research in each area and incorporate in our discussions recent reports of well-designed individual physical activity intervention studies that expand the existing research base and/or target new areas of research. Our second purpose is to offer new ideas and recommendations to improve the state of the science within each area and, where possible, to propose ideas to help bridge the gaps between these existing categories of research. **(*Circulation*. 2006;114:2739-2752.)**

Key Words: AHA Scientific Statements ■ exercise ■ health behavior ■ intervention studies ■ metabolism ■ motor activity

Sedentary behavior has been identified as one of the leading preventable causes of death,[1] and an inverse linear relationship exists between volume of physical activity behavior and all-cause mortality.[2] Moreover, participation in regular physical activity decreases the risk of cardiovascular disease,[3] type 2 diabetes mellitus,[4] osteoporosis,[5] depression,[6] obesity,[7] breast cancer,[8] colon cancer,[9] and falls in older adults.[6] Given the numerous health benefits of physical activity participation, various public health guidelines have been published on the recommended volume and intensity of physical activity for healthy adults. The American Heart Association, the US Surgeon General, the Centers for Disease Control and Prevention (CDC), and the American College of Sports Medicine recommend at least 30 minutes per day of at least moderate-intensity physical activity on most, and preferably all, days of the week.[10–12] Similar guidelines have been adopted for children,[13] although other consensus panels have recommended one[14,15] or more[16] hours of physical activity per day for children. The CDC, American College of Sports Medicine, and Surgeon General further state that physical activity may be incorporated into one's everyday lifestyle and that the daily physical activity requirements may be accumulated over the course of the day in short bouts of 10 to 15 minutes. Finally, the US Department of Agriculture has

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recommended 30 minutes of physical activity per day to prevent chronic disease and at least 60 minutes per day to manage weight.[17]

Despite the numerous benefits of physical activity and the recent attention to specific guidelines, only 32% of US adults and 66% of children and adolescents (based on Healthy People 2010 guidelines) engage in regular leisure-time physical activity.[18,19] Given the many benefits of physical activity and the low prevalence rates, it is imperative that interventions be designed that effectively promote the adoption and maintenance of active lifestyles in large numbers of people.[13] Exhaustive reviews of physical activity intervention studies have been conducted that provided quantitative indices of physical activity intervention efficacy,[20,21] as well as recommendations for efficacious and cost-effective physical activity promotion strategies.[22–24] However, these previous exhaustive reviews have not addressed issues specific to population subgroups or intervention-delivery modalities. Numerous additional reviews of physical activity interventions have focused on these particular subareas of physical activity intervention research (eg, Blamey and Mutrie[25]); however, these reviews are published in a wide array of journals and formats and often do not address broader intervention issues, such as integration of intervention modalities.

We share the view of numerous authors in the field who have argued that increasing physical activity on a public health level will require a comprehensive paradigm that incorporates and, where possible, integrates approaches that target various subpopulations and uses various delivery modalities (eg, Riddoch[26]). In addition, we believe it is crucial to continue to develop more effective approaches to physical activity promotion. Thus, the purpose of the present review is 2-fold. First, we provide an overview of existing physical activity intervention research, focusing on subpopulations and intervention modalities. Our reviews within each area are not exhaustive or quantitative, because each area has been reviewed in more depth in numerous other reports. Instead, our goal is to provide a single document that provides a qualitative overview of intervention research that emphasizes selected topics of particular importance for improving the population-wide impact of interventions. Therefore, in synthesizing this vast literature, we begin with existing reviews of physical activity research in each area and incorporate in our discussions recent reports of well-designed individual physical activity intervention studies that expand the existing research base or target new areas of research. Our second purpose is to offer new ideas and recommendations to improve the state of the science within each area and, where possible, to propose ideas to help bridge across these existing categories of research.

Specifically, we more closely examine the state of physical activity interventions research within (1) specific populations, such as among different age groups and within underserved populations, and (2) across different delivery modalities, including healthcare or physician-delivered interventions, worksite interventions, mediated interventions, environmental interventions, and multiple behavior change interventions that include physical activity. These categories of intervention research are not mutually exclusive or exhaustive, but we believe improvements in these areas hold promise for improving the population impact of interventions. We then discuss cross-cutting issues that impact multiple areas of physical activity intervention research, including (1) maintenance of physical activity behavior change, (2) theory testing and development, and (3) diffusion and policy implications. Throughout the review, we discuss research that focuses on increasing physical activity behavior within healthy child, adult, and older adult populations. Discussion of the physiological benefits of physical activity behavior among healthy and clinical populations can be found elsewhere.[3,26]

Physical Activity Interventions Within Specific Subpopulations

Age Groups

Summary of the Evidence

The vast majority of intervention research has targeted young to middle-aged adults, typically defined as ages 16, 18, or 21 to 65 years, or has enrolled participants predominantly of this age group. In the most comprehensive reviews of intervention studies, findings from studies targeting this age group have demonstrated moderate effects overall, with stronger effects in studies in which behavior modification was used (eg, Hillsdon and Foster[21]). However, there is substantial heterogeneity across studies, and we have little evidence for long-term maintenance of these effects.[20,21] Additional information about studies of young to middle-aged adults is presented in later sections of this report, after the discussion of age groups.

The literature examining physical activity interventions among older adults has grown tremendously in the past decade. Recent reviews have attempted to synthesize this literature,[27–32] with reviewers' definitions of older adults ranging from a minimum age of 40 years[28,32] to a minimum mean sample age of 65 years.[30] In general, interventions among older adults, including face-to-face and telephone interventions and individual and group interventions, have been effective in increasing physical activity behavior, at least in the short term. These interventions typically have multiple components and involve some combination of educational, behavioral, and cognitive-behavioral strategies.[30] Although it is difficult to disentangle the most effective intervention components, general health education alone does not appear to be an effective method of promoting physical activity in older men and women.[27,28] Cognitive-behavioral interventions such as self-monitoring and goal setting have been effective in several studies.[29] In terms of setting, in a recent review that compared home- versus center-based physical activity programs among participants >50 years old, center-based programs appeared to be superior in the short term for producing fitness outcomes among those with cardiovascular disease, although adherence to physical activity programs was superior in home-based programs.[31] Thus, physical activity promotion among older adults has shown some short-term efficacy when programs have gone beyond educational approaches.

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Although fewer studies have been conducted among children and adolescents, this literature has also grown within the past few years, with a diversity of intervention modalities and results. Most interventions targeting children and adolescents have been school-based, and reviews of these studies have shown inconsistent and at best modest short-term increases in physical activity during the school day among children and adolescents. Moreover, studies that have exhibited physical activity increases have not generalized to outside the school setting, and maintenance of physical activity increases has either been poor or not assessed.[33–36] A review of noncurricular approaches to physical activity promotion indicates some limited efficacy for physical activity promotion during school break periods, whereas the few studies examining after-school or active school travel programs have suffered from high dropout rates and thus far have yielded inconclusive results.[37] In general, though, school-based programs that have included policy and environmental approaches have been more effective than curriculum-only approaches.[34] It has been argued that family- and community-based programs have greater potential than programs operating in schools only, because of the potential multilevel approach; however, reviews indicate that the few studies conducted thus far have not demonstrated significant increases in physical activity among youths.[33,36] Alternatively, recent studies conducted among American children 8 to 12 years old,[38] adolescent girls,[39] and French middle school students[40] have demonstrated preliminary evidence that targeting a reduction in sedentary behaviors in youth may be an effective strategy for increasing physical activity. The most extensive youth physical activity intervention was the CDC-sponsored VERB campaign, which targeted 9- to 13-year-olds with paid media advertisements and community events.[41] Physical activity increased in those exposed to the campaign, which indicates a positive nationwide effect. Although there are several effective physical education and multicomponent school-based interventions, as well as promising programs for reducing sedentary behavior, intervention approaches in home and community settings have not been promising.

Research Recommendations and Future Directions

Research has typically focused within different ages or developmental periods, which results in the loss of potential opportunities to capitalize on natural interactions and synergies that occur across generations. The family represents one such naturally occurring multigenerational unit. Observational studies underscore the influence of parents and other family members on the physical activity patterns of children.[42] Surprisingly few attempts to formally target the family in promoting regular physical activity have occurred, however, and results from family-based interventions have been mixed.[43,44] A challenge remains to find ways to get all family members (including fathers) to participate regularly, as well as to expand the site of such interventions beyond institutional settings (eg, schools) to the home environment, where a large portion of daily family interactions occur.

A second approach that has emerged has been to target specific intergenerational dyads for intervention, such as mother-daughter pairs. Such approaches capitalize on the similar motives and challenges faced by women across generations related to physical activity and other lifestyle behaviors.[45] Programs such as those reported by Ransdell and colleagues[46] that have targeted middle-aged mothers and their teenaged daughters have found significant short-term (12 weeks) improvements in endurance, muscular strength, and flexibility among both dyad members, regardless of whether the program was performed in a community setting or in or near the participants' homes.[46] Other innovative approaches to family-based interventions need to be evaluated.

A wide range of other opportunities exist for intergenerational physical activity interventions that await systematic investigation. Such opportunities can capitalize on circumstances in which different generations naturally coexist or interact. For children and their parents, moments of opportunity can occur around children's sports play, with parents using a portion of the time that their children are on the field to engage in their own forms of physical activity, such as walking. On the other end of the age continuum, many older adults live in senior residential settings,[47] and innovative partnerships have been developed between such congregate housing settings and colleges that could set the stage for intergenerational collaborations on physical activity and other lifestyle interventions.[48] Multigenerational neighborhoods provide an additional locale for the promotion of physical activity across age groups. Taking advantage of activities such as "neighborhood watches" that encourage neighbors to walk together to ensure local safety is one way that physical activity can be promoted regularly. Finally, targeting community settings where multiple generations gather on a regular basis, such as places of worship, has promise for reaching a wide range of population groups.[49]

Underserved Populations

Summary of the Evidence

We define underserved populations as those of ethnic and/or racial minority status and those of low socioeconomic status (SES). In general, few studies of the effectiveness of physical activity promotion interventions have targeted or included substantial numbers of racial/ethnic minorities or people from low-income backgrounds.[50–53] Interventions that target general populations typically do not report separately on underserved populations or do not have enough people in their samples to conduct subgroup analyses.[52] Moreover, whereas most low-SES people are white, most of the low-SES individuals in the scant literature presenting such subgroup analyses are of racial/ethnic minority backgrounds. A small number of studies have specifically targeted underserved populations for physical activity promotion interventions. Among these studies, findings are mixed, but the results are generally weak and often characterized by high attrition rates.[50–52] In a review of racially and/or ethnically inclusive community-level studies, outcome data on physical activity behavior change were presented in fewer than half of the studies, with few significant effects and modest effect sizes.[52]

More recent contributions to the literature on racially and/or ethnically inclusive, individually targeted interventions have included larger samples and more rigorous designs than earlier studies.[54] Smaller-scale cardiovascular disease

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prevention research projects targeted to high-risk groups have also begun to be implemented by public health agencies and their academic, managed care, safety net clinic, and other community partners. This approach is exemplified by the 12 CDC-funded WISEWOMAN (Well-Integrated Screening and Evaluation for WOMen Across the Nation) projects aimed at providing cardiovascular disease prevention services to the low-income, predominantly racial/ethnic minority women screened by the National Breast and Cervical Cancer Early Detection Program.[53] Results are promising, with 4 studies producing significant physical activity–related changes, including increased levels of regular moderate-to-vigorous physical activity[55,56] and physical activity stage of change advancement.[57,58] Another recent study showed initial efficacy for a physical activity counseling program based on the transtheoretical model, which targeted low-income, predominantly white women who had at least 1 child enrolled in a health resources program.[59] Taken together, physical activity intervention research among underserved populations has been sparse and fraught with methodological problems; however, more recent and well-designed studies have begun to show positive results for interventions targeted to specific populations of racially and/or ethnically diverse and low-SES individuals.

Future Directions and Research Recommendations

Thus far, most studies have focused on what it takes to recruit and retain underserved populations in research studies, not what it takes to achieve and sustain engagement in regular physical activity. Ethnically inclusive studies have necessarily placed great emphasis on the process of intervening, to gather data on racial/ethnic groups largely absent from other studies. These processes include involving communities and building coalitions from inception; targeting audiences that are already assembled; engaging "cultural insider" investigators in leadership roles; mobilizing social networks; and cultural tailoring of messages and messengers.[60]

Although a general understanding of intervention processes has developed, improving methodology in this area must be applied to more specific questions about program implementation. For example, future studies should include more diverse samples, both increases in the numbers of racial/ethnic minority or low-income individuals in general to permit ethnic-specific analyses and increases in the number of studies targeted to specific racial/ethnic minority groups.[51,52] Theory-based intervention research is needed, as well as use of strong experimental designs and development and use of instruments that are valid and meaningful for the targeted population.[50–52] As in most other areas of physical activity research, longer follow-up is encouraged.[51] Some studies have used interventionists of the same ethnicity as the participants, but the impact of this kind of matching needs to be studied.[51,61] Similarly, future research needs to examine the importance of tailoring interventions to each cultural subgroup. Although such tailoring is often recommended and has been attempted, we do not yet know how much specificity is optimal or how best to tailor interventions to cultural needs.[50,51]

Another developing area of research among underserved populations is reflected in the more recent community-level interventions, which focus more on community norms and other environmental strategies than earlier efforts.[52] The push for greater intervention at the level of the physical environment[62] is certainly indicated in communities of nonwhites and lower-income communities, with their few recreational facilities and opportunities.[63–65] Physical and structural changes are costly and time-consuming, however, and tend to assume lower priority in low-resource areas with so many pressing needs.[66] In addition, underserved communities experience more substantial cultural and economic barriers to physical activity participation.[52,67] For instance, among black girls and women, arduous hair maintenance is a disincentive to perspire,[68] and the higher levels of perceived exertion associated with their higher rates of obesity may discourage more vigorous activity (eg, stair climbing) or longer physical activity bouts.[69] Perhaps as a result, many environmental interventions, as implemented, have been less effective or ineffective in racially, ethnically, and/or socioeconomically marginalized population segments. Thus, immediate attention must be given to the sociocultural environment to address these barriers as a complement to efforts to change the physical environment. Examples include incorporating structured physical activity breaks into organizational routines in churches,[70] public agency worksites,[71,72] and community-based organizations[73]; slowed elevators or those that skip floors; and distant parking lots in worksites.[74]

Physical Activity Intervention-Delivery Modalities

Interventions in Healthcare Settings

Summary of the Evidence

Interventions delivered in the context of the primary healthcare system have varied in terms of who delivers the intervention, the duration and intensity of the intervention, and intervention components. In general, previous reviews indicated that interventions in healthcare settings can increase physical activity, at least for short-term follow-up.[75–79] Some research has shown that even brief (3 to 10 minutes) interventions can increase physical activity,[76,80] and although physicians typically delivered the advice, effective interventions often involved other members of the healthcare team, such as nurses and health educators.[76,79] Written prescriptions provided in addition to verbal advice may enhance the effectiveness of interventions.[76,77,79] Multiple-component interventions that include behavioral strategies such as goal setting, problem solving, self-monitoring, and feedback, as well as supervised exercise and provision of equipment, have generally been more effective than advice only, although these findings have not been entirely consistent across studies.[79] Technological innovations such as using the Internet or making automated phone calls may reduce the effort and cost of interventions, although further research is needed to clarify this.[76,79]

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A number of international studies of primary care–based physical activity promotion programs have been conducted since the most recent of the reviews cited above and have revealed mixed findings. One study conducted in England found increases in physical activity only among those in the more intense prescription-plus-counseling intervention,[81] whereas another study, conducted in Switzerland, found increases in physical activity that did not differ across intervention intensities.[82] An Australian study found no effects for physician advice,[83] whereas an English study found that physician referral and reduced fees to local fitness facilities increased physical activity at 6-month but not 12-month follow-up.[84] Finally, a study conducted in Spain found that physician counseling improved physical activity among adolescents at 6- and 12-month follow-up. These recent studies may be viewed as a microcosm of the previous research base, with a range of designs and methodologies, revealing mostly positive results, but with some inconsistency and lack of clarity as to what intervention type and intensity works best for whom and for how long.

Future Directions and Research Recommendations

More randomized controlled trials are needed to overcome the methodological limitations of existing studies. Issues that future studies need to address include methodological improvements, such as recruiting representative samples of participants[79,85] and providers/clinic settings,[76] reporting attrition and adverse events,[77] and assessing the fidelity of intervention delivery.[85] Intervention characteristics that need additional study include a focus on moderate and lifestyle activities versus higher-intensity activity and discrete episodes of activity[78,79,85]; the relative effectiveness of interventions that target physical activity alone versus those that also target other risk factors[79]; how to implement interventions over time, taking into account the natural variability in patient activity over time[76,77]; and how best to adapt interventions to community barriers and resources.[76,77,85] Several researchers have also recommended reporting data on costs and examining the cost-effectiveness of interventions.[76,78,79,85] Providers require training and time to deliver the interventions, and issues of reimbursement and motivation have yet to be resolved.[78]

Worksite Interventions

Summary of the Evidence

Because of the potential for broad reach, the worksite has been examined in numerous studies as a setting for physical activity interventions. However, the evidence in support of worksite interventions has been mixed at best. A meta-analysis of worksite intervention studies performed before 1998 revealed little or no effects of these programs on increasing physical activity behavior.[86] Conversely, a more recent and more selective review of studies with the highest methodological quality showed strong evidence for increases in physical activity as a result of worksite interventions, although successful strategies within these programs were not discussed.[87] Yet another recent review of studies conducted since the 1998 review revealed somewhat more positive findings.[88] Specifically, programs offering onsite fitness facilities or referrals to worksite fitness programs showed little efficacy and generally were attended mostly by those who were either already exercising or highly motivated to do so.[88] There was stronger evidence in support of individually tailored motivational programs guided by behavior change theory, as well as programs using strategically placed prompts to, for example, encourage stair use, although even among these more successful interventions, physical activity gains were typically short-term.[88] A more recent study conducted in 5 Canadian workplaces showed significant increases in steps taken per day after a 12-week counseling and self-monitoring intervention, although data beyond the 12 weeks were not available.[89] Taken together, more recent and methodologically sound workplace interventions have shown generally favorable outcomes, especially when they have used individually tailored theory-based materials and/or environmental prompts, although the generalizability of these effects across less motivated employees and for long periods of time has not been established.

Future Directions and Research Recommendations

As with other intervention areas, worksite intervention research could benefit from studies that use more inclusive sampling designs, thus including employees who may be less motivated to change at intervention outset. Additionally, although methodology has generally improved, more randomized controlled trials that specifically and comprehensively test and report on specific intervention protocols could improve our understanding of exactly what intervention components are most efficacious.[86] Although previous programs have tended to operate either on the individual level or on the organizational/environmental level, future studies should test more comprehensive approaches that combine previously efficacious intervention components, such as individually tailored, theory-based programs, with environmental prompts. Additional environmental interventions that remain to be tested include adding shower facilities, bike racks, walking trails, and stairway enhancements. Future studies could also benefit from longer follow-up periods, with programs that are incorporated into the organizational structure and thus are not seen as interventions but rather as part of the regular workplace culture.[88] Within this framework, technology that allows for delivery of theory-based, individually tailored messages through e-mail, Internet, or personal data assistant devices should be used to allow for easier integration with other workplace tasks (see also "Mediated Interventions"). Finally, incentive systems should be developed that can provide valued rewards for positive behavior change that do not undermine intrinsic motivation or workplace productivity.

Mediated Interventions

Summary of the Evidence

Interventions that are delivered through means other than face-to-face media, such as print, telephone, or the Internet, have been referred to as mediated interventions.[90] Mass-media campaigns deliver circumscribed messages on a local or regional population level through some combination of television, newspaper, or radio. Reviews of these interven-

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tions have generally shown that they can produce consistent recall of campaign messages, but they have shown mixed results in terms of attitude change and have not impacted behavior change in the targeted populations.[88,91–93] An exception is the national VERB campaign for youth, which showed very high "brand" awareness and message recall with evidence of physical activity change, especially in those exposed to the messages. The particularly positive effects could be due to the large budget for purchasing ads, combined with coordinated community events.[41] Smaller mediated-intervention trials typically deliver more comprehensive messages and target a more specific subpopulation, such as employees of a company or research volunteers. Such interventions may be targeted toward a particular subgroup, such as older adults, or individually tailored on the basis of feedback from participants on, for example, their specific motivational readiness, expected outcomes, or self-efficacy. Reviews of mediated interventions that use print-based programs indicate moderate efficacy in increasing physical activity behavior, although further evidence is required to support longer-term maintenance of behavior change.[88,90,93] Evidence in support of telephone and Internet programs has been mixed.[88,90,93,94]

Future Directions and Research Recommendations

Further research should pursue better understanding of the minimal amount of face-to-face contact necessary for behavior change and related cost-effectiveness issues. Questions concerning the most effective channel or combination of channels (eg, print, telephone, or Internet) for intervention delivery must be answered, including examination of what delivery channel works best for whom and whether preference for a particular delivery channel impacts effectiveness. Researchers should further explore the efficacy of theory-based individual tailoring of mediated motivational messages. For example, recent interventions have used expert systems, which are computer-generated messages created by physical activity promotion experts that are designed to respond to individuals on the basis of their responses to theory-based questionnaires.[95] These expert systems have been used successfully to promote physical activity through print media.[93,96] Similar physical activity counseling programs have been delivered over the telephone, offering an alternative for those who may not have Internet access or those who prefer "human" contact.[94] After initial costs to develop these expert systems, such programs, especially when delivered over the Internet, incur little incremental cost with the addition of each new user and thus have the potential to reach large numbers of individuals with personalized interactive materials. Moreover, the potential for greater participant adherence exists, because participants are often able to engage in the intervention at their own convenience. Despite the potential upside of these programs, further research is necessary to test their efficacy, cost-effectiveness, and reach, especially to underserved populations.

Environmental Interventions

Summary of the Evidence

Environmental interventions impact physical aspects of the environment in an attempt to promote physical activity for leisure and transportation purposes. Despite numerous studies examining associations between environmental variables and physical activity behavior,[97–100] very few controlled intervention studies have been conducted. A review[101] of environmental interventions identified 3 multicomponent environmental interventions conducted in workplace or military settings that used strategies such as providing additional exercise facilities and providing more time and incentives to use these facilities. These interventions showed small increases in rates of physical activity compared with controls, but each study had multiple potential sources of bias, including use of quasi-experimental designs. The authors also identified 19 studies that tested the effects of prompts to use stairs on subsequent use of stairs instead of elevators or escalators. Again, most studies suffered from multiple design flaws and lack of adequate controls, but in general, they revealed weak, short-term effects. The Task Force on Community Preventive Services[24] located 10 studies of sufficient quality to be included in an evidence-based review of environmental interventions to increase access to physical activity. The median estimates from these studies suggest that creating or improving access to places for physical activity can result in a 25% increase in the number of people who are active at least 3 times per week. The Task Force strongly recommends community-level interventions that create or enhance access to places for physical activity. Finally, a recent study that examined change in physical activity among residents living near a newly constructed walking trail found no increases in several indices of physical activity. In summary, although research on the relationship between environmental variables and physical activity behavior continues to grow, the few intervention studies conducted have shown weak effects at best, and these studies have multiple methodological weaknesses.

Future Directions and Research Recommendations

Environmental research on physical activity has become an active area of investigation, facilitated by application of ecological models of behavior[102–104] and development of specific models of environmental factors and physical activity.[42,62,99] Numerous cross-sectional studies have been conducted to inform policy decisions about parks, trails, the overall design of communities, and transportation investments. Access to recreational facilities and the esthetics of those places have been consistently related to recreational physical activity.[97] A systematic review by the Transportation Research Board and Institute of Medicine[97] concluded that built-environment variables are related to physical activity, and there are many opportunities to change built environments. A recent report from the Community Guide[105] similarly concluded that community-level patterns of land use and transportation infrastructure that support walking and cycling to nearby destinations are related to physical activity. Although virtually all of these studies were cross-sectional, land use and transportation infrastructure interventions were recommended, because randomized intervention studies are not feasible to evaluate community-scale changes. However, there are many research needs. Smaller-scale environmental interventions, such as sidewalk improvements and small-scale redevelopment, could be studied with quasi-experimental designs. Assessment of the causality of

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community-scale built environments could be enhanced by quasi-experimental studies of people moving to new neighborhoods. Implementation of planned interventions is likely to vary widely, and thus, careful process measurement will be important. Economic evaluations are needed, such as those that focus on the cost-effectiveness of built-environment changes in relation to a variety of issues, including healthcare costs, injury, air quality, and performance of nearby businesses. Use of objective measures of environments and further examination of how environmental and psychosocial variables interact in their associations with physical activity are also needed.[97,99,100]

A critical feature of environmental research is the necessity for transdisciplinary collaboration.[104,106,107] Health researchers generally lack expertise in the conceptual models, measures, research designs, and statistical approaches needed to study physical environments and policies. It is necessary to combine skills from a variety of disciplines to develop concepts and methods for this new field of study. Public health, behavioral science, and exercise science researchers are now collaborating with colleagues from the urban planning, transportation, civil engineering, recreation and leisure study, geography, landscape architecture, architecture, economics, and policy fields. Several of these disciplines are actively engaged in new interdisciplinary investigative groups.[108]

Multiple Behavior Change Interventions That Include Physical Activity

Summary of the Evidence

A number of interventionists have targeted physical activity within the context of multiple health behavior change programs. For example, the Lifestyle Heart Trial tested an integrated program that targets a 10% fat vegetarian diet, moderate aerobic exercise, stress management training, smoking cessation, and group psychosocial support.[109] Particular attention has been paid to interventions to promote physical activity and healthy eating. A recent review examined 17 well-controlled studies that targeted physical activity and healthy eating among adults in community, worksite, or medical clinic settings.[110] The majority of studies targeted either weight loss or diabetes prevention and used a combination of educational and behavior change components. Eleven of the 17 studies showed significant positive changes in physiological outcomes and/or physical activity and healthy eating behaviors. Outcomes were generally maintained during follow-up periods of up to 5 years only to the extent that intervention programs continued.

A number of recent studies examining eating and physical activity interventions have been published since this review. Two studies found significant increases in both healthy eating and physical activity relative to controls among older adults (≥65 years) receiving theory-based booklets at hospital outpatient clinics[111] and among middle-aged to older adults[43–81] from the community who signed up for educational workshops,[112] although outcomes in these studies were measured at 2 and 6 weeks after baseline, respectively. Another recent study that targeted weight management among overweight or obese adults showed significant improvements in healthy eating and physical activity at a 2-year follow-up for participants in both the individually tailored and generic informational treatment conditions.[113] Thus, taken together, recent well-controlled studies generally support the targeting of physical activity and healthy eating behavior, at least for short-term effects.

Future Directions and Research Recommendations

Although research has indicated that programs that target both physical activity and healthy eating can be effective, much more research is needed on whether and how to combine behavioral interventions. For example, behavioral interventions for different behaviors can be (1) separate and uncoordinated; (2) separate and coordinated, including simultaneous interventions and/or sequential interventions; and (3) integrated, where 1 behavioral intervention is incomplete unless accompanied by another intervention(s). Some research has begun to examine the strengths and weaknesses of these different modes of multiple behavior change delivery. For example, a recent study concluded that in underserved populations, readiness to change behavior was unique for each behavior, so that sequential (nonintegrated) interventions appear more appropriate when they affect multiple risk behaviors, particularly physical activity and diet.[114] Similarly, other recent studies have shown no additional effects of targeting both physical activity and healthy eating relative to a single behavioral target, either among adolescents[115] or among older adults.[116] Conversely, another study showed that although simultaneous and sequential interventions that target physical activity and healthy eating among Belgian adults were both superior to a control condition, participants receiving the simultaneous interventions reduced fat intake more than those receiving the sequential interventions.[117] Less research has combined physical activity interventions with other targets of health behavior change. With respect to physical activity and smoking, a randomized clinical trial showed that vigorous-intensity physical activity enhanced the effects of cognitive behavioral smoking cessation treatment among women,[118] whereas other studies using moderate-intensity physical activity have produced null findings.[119,120] Research to improve understanding of how best to target changes in multiple health behaviors is a high priority because a large proportion of people have more than 1 behavioral risk factor for cardiovascular and other chronic diseases.

Cross-Cutting Issues

Maintenance of Physical Activity Behavior Change

Structured exercise programs have reported dropout rates that range from 9% to 87% ($\bar{x}$=45%), which highlights the compliance problem among those who voluntarily initiate physical conditioning regimens.[121] Although widely differing durations and definitions of "exercise dropout" may have contributed to the variability in results, it appears that exercise is not unlike other health-related behaviors in that typically half or less of those who initiate the behavior will continue, irrespective of initial health status or type of program. Others who do not technically meet the definition of an "exercise dropout" may continue the program but at a subthreshold intensity, frequency, or duration. Because exer-

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cise is voluntary and time consuming, it may compete with vocational responsibilities or other valued leisure-time interests. Structured programs can create additional barriers for some people, including scheduled class times, need for travel to the facility, and entrance fees. According to 1 study, patients undergoing gymnasium-based exercise training spent more time in their cars going to and from the programs than patients in a home-training comparison group spent on their cycle ergometers.[122] Several randomized trials have shown that a lifestyle approach to physical activity among previously sedentary adults may provide an effective alternative to the traditional structured approach to physical activity promotion (eg, Dunn et al[123]). Although structured exercise programs may be appropriate in some populations and settings, physicians and exercise professionals should consider broadening their recommendations from structured exercise programs to promotion of increased moderate to vigorous physical activity in daily living (eg, park the car away from stores when shopping, take the stairs instead of the elevator).

Although some advantages of lifestyle approaches have been established, dropout rates for such programs can be even more difficult to establish, especially outside the research context. In lifestyle intervention studies, rarely are outcomes measured more than 1 year after baseline, and fewer assess outcomes after a period of no intervention. More typically, maintenance periods include continuation of the intervention or a tapered, less-intensive version of the initial program. Across intervention subareas within the present review, it appears maintenance of initial physical activity change is directly related to the intensity of the intervention program during the maintenance period. Once interventionists, and the incentives they provide, are no longer salient, physical activity tends to decline. Although there has been considerable research on the determinants of physical activity adoption, some researchers have identified factors that may specifically affect physical activity maintenance (eg, Marcus et al[95]), although further research is needed in this area.[95]

There is no shortage of calls for greater study of physical activity maintenance and improved maintenance interventions; however, there are barriers to conducting research in this area. First, because physical activity usually declines after interventions cease,[95] more recent studies usually include reduced or modified interventions after the initial intensive interventions. As a result, we are learning little about what happens to physical activity behavior after all intervention components have ceased. Another barrier to research on physical activity maintenance is that participants must first become active before an intervention's impact on behavioral maintenance can be evaluated. Thus, interventions that do not result in initial behavior change cannot evaluate behavioral maintenance, and examinations of participants who do initially increase activity cannot be causal, because randomization typically occurs at the beginning of the intervention. One potential solution to this problem is to rerandomize initially successful participants into 1 of 2 or more maintenance interventions. Another possibility is to recruit and randomize already active participants into physical activity maintenance programs. Additionally, researchers must develop or refine theoretical models to address the particular factors that lead to behavior maintenance, rather than assuming that the same factors that explain behavior onset will also operate during maintenance.[124]

Theoretical Paradigms

Early physical activity research was largely atheoretical; however, in the last decade, there has been greater focus on the importance of theory.[125] Theories that have been used most often in intervention research fit under the larger umbrella of social learning theory (SLT) or social cognitive theory (SCT). These 2 labels are often used interchangeably, although the latter is associated with Bandura's[126,127] model that emphasizes the importance of self-efficacy beliefs, whereas the former can be traced to expectancy-value conceptualizations concerning expected outcomes and their perceived importance as the primary determinants of behavior.[128] As currently used, both SLT and SCT are built on the principle of triadic reciprocal causation, in which personal (eg, cognitive and demographic), environmental (eg, social environments), and behavioral (eg, characteristics of physical activity, such as intensity) factors are thought to be mutually influential.[126] Other social cognition models often used in physical activity research, such as the health belief model,[129] theories of planned behavior[130] and reasoned action,[131] and protection motivation theory,[132] share the same underlying assumptions and, for the most part, posit similar behavioral determinants but differ with respect to the number of proposed influences and how these determinants are causally or temporally ordered. Another model often used in physical activity research is the transtheoretical model, which includes 10 processes of change that are said to drive peoples' progression through 5 stages of change.[133]

Physical activity intervention researchers who describe interventions as employing SLT or SCT typically use any number of intervention strategies and techniques that fit within that global framework rather than identifying a specific social cognition model. As a result, numerous interventions claim to use an SLT or SCT framework but actually use a diversity of theory-based techniques in differing contexts and sequences. This trend has made it more difficult to test the utility of any specific theoretical model.[134] Moreover, effective testing of theoretical models within an intervention study requires assessment of theoretical constructs at regular intervals throughout the intervention trial, followed by a mediator analysis to test whether or not increases in physical activity are actually due to change in the theoretical constructs.[125] Although research on theoretical mediators of physical activity behavior change is crucial to moving the field forward, it is rarely conducted adequately.[135] One review[135] uncovered only 12 studies that used established techniques for mediator analysis (eg, Baron and Kenny[136]). Because of the small number of studies and numerous methodological issues, such as lack of power, the authors were not able to draw conclusions as to the key mediators of physical activity change.[135] A recent study showed self-efficacy was the only one of 4 targeted mediators to partially mediate the effects of a school-based physical activity intervention for adolescent girls.[137] It is crucial that more intervention researchers construct and adequately test specific

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hypotheses about what theoretical factors will be changed and at what times during the course of the intervention.

Although few physical activity studies have tested theory, a number of new ideas in theoretical research on physical activity behavior have taken shape in the last several years. For example, most social cognition models do not explicitly elucidate the processes that underlie behavior initiation versus maintenance; however, some researchers have begun to posit different sets of factors that determine intention formation, behavior onset, and behavior maintenance.[138–140] Others have examined the impact of a broader range of social-cognitive variables on physical activity behavior, including expected affective responses to physical activity, the role of potential moderators of expected outcomes, such as outcome value and temporal proximity, and the role of perceived satisfaction with the outcomes of increased physical activity as predictors of behavioral maintenance.[138,141,142] Finally, the Institute of Medicine report on health and behavior concluded that collaboration among multiple disciplines is required for understanding and influencing health and behavior, because health and disease are determined by dynamic interactions among biological, psychological, behavioral, and social factors.[143] For physical activity research, the importance of a broader theoretical approach, termed "transdisciplinary" research, has been articulated.[104,108] A primary goal is to improve ecological models of physical activity behavior, which describe how coordinated (if not synergistic) interventions can operate at several levels (eg, individual, interpersonal, organizational, community, policy, and built environment) to influence behavior more effectively than single-level interventions.[62] For example, environmental variables are a part of the triadic reciprocal causation scheme that has been largely ignored in applications of SCT but has been brought back into focus with newly applied versions of ecological models.[102–104] These models are explicitly multilevel and can encompass the intrapersonal, interpersonal, and behavioral components of other models, but they highlight the role of physical environments and policy influences that are largely absent in other models.[42,62,99]

Diffusion and Policy Issues

The public health effect of any intervention depends on the combination of its effectiveness, extent and quality of its implementation, and sustainability.[144] The diffusion of health behavior change innovations has been described as having 5 phases.[145] The first phase is innovation development, in which the program is developed and evaluated. The second phase is dissemination, in which it is communicated widely so the effective program is available for adoption. The third phase is adoption, which can be defined as purchasing materials or participating in training. The fourth phase is implementation, in which users put the program into practice, and fidelity to the procedures used in the original research phase needs to be considered. The final phase is maintenance, or the sustained use of the innovation by adopters. In this phase, both the quantity (eg, percent of teachers using the program regularly) and quality of implementation (eg, adherence to the curriculum) need to be considered. A literature review revealed that only 1% of health promotion articles could be considered diffusion research, and 6% were classified as institutionalization or policy change studies.[145] Although these low percentages are likely to apply to the physical activity intervention literature, there are some notable exceptions of successful program diffusion.

Active for Life (www.activeforlife.org) is a program of The Robert Wood Johnson Foundation that is evaluating the diffusion of 2 evidence-based physical activity interventions for older adults. Two recent articles report evaluations of the diffusion of 2 programs for elementary schools. The CATCH (Child and Adolescent Trial for Cardiovascular Health) program was found to be effective in changing physical activity and nutrition during and after the trial.[146] Former intervention and former control schools, along with new control schools, were evaluated 5 years after the study to assess continuation of components of the CATCH program. Former intervention schools had higher institutionalization scores than former control schools, and participation in training was the best predictor of long-term effects.[147] SPARK (Sports, Play, and Active Recreation for Kids) was a health-related physical education program that produced several favorable outcomes. An independent evaluation of the diffusion of the program was conducted in schools not involved in the original study.[148] A large majority of teachers trained in SPARK continued to use the program up to 4 years after training. These 2 studies indicate that school-based physical activity programs can be diffused and maintained; however, the diffusion of additional evidence-based programs needs to be documented. Even more importantly, effective methods of diffusing evidence-based programs need to be developed so what is learned from intervention studies can be translated to public health improvements.

Diffusion of programs often involves intervening on the policy level. Policies are rules, regulations, and guidelines that can be adopted by many types of organizations. Because policies are the result of deliberations and political processes, often involving tradeoffs in resources, it is useful to have research to inform policy decisions. It is possible to base some policy recommendations on existing research. Many policies appear to provide incentives for people to be inactive, but it is difficult to identify current policies that reinforce physical activity. For example, employees are reimbursed when they travel by car, but not for walking or cycling trips. Medical insurance pays for the treatment of diseases caused by sedentary lifestyles, but most companies provide no incentives for people to be active and prevent those diseases. The effects of these and other incentive-related policies need to be evaluated.[149]

Summary and Conclusions

Although there is a great need for continued research on the efficacy and cost-effectiveness of various physical activity interventions and ways to help people maintain behavior change, much progress has been made over the past decade. Studies of younger to middle-aged adults have demonstrated moderate effects overall, although stronger effects are evident for interventions that use behavior modification. Moreover, stronger effects are present for the adoption phase of physical activity, although few studies have examined longer-term

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maintenance.[20,21] Recent and ongoing studies that focus on lifestyle physical activity in addition to or instead of structured, class-based activity will likely contribute to our understanding of the options available for assisting adults with physical activity behavior change. In studies of older adults, short-term efficacy has been demonstrated for behaviorally oriented approaches, although long-term maintenance has not been as strong. Although several enhanced physical education programs have been shown to be effective and are being disseminated, researchers have not yet found other consistent methods for promoting youth physical activity in school-, community-, and home-based settings. Targeting community settings where multiple generations gather on a regular basis, such as places of worship, has the potential for reaching individuals of varying ages and racial and ethnic backgrounds.[49]

Physical activity intervention research among underserved populations has been limited; however, more recent and well-designed studies have been promising, because they show positive results for interventions targeted to specific populations of ethnically diverse and low-SES individuals. Future studies should include more diverse samples and should focus on both the adoption and the maintenance of physical activity behavior.

Interventions in healthcare settings can increase physical activity, at least for short-term follow-up.[75–79] Some research has shown that even very brief interventions can increase physical activity.[76,80] Although most studies have focused on assisting the physician with counseling about physical activity, in future research there should be a focus on working with the allied health professionals in primary and specialty care settings.

Because most adults spent much of their time at work, the worksite has been examined in numerous studies as a setting for physical activity interventions. Although the overall evidence in support of worksite interventions has been mixed, stronger evidence supports individually tailored behavior-change–oriented programs at the workplace.[88] Future studies should continue to use these more effective approaches and study employees over longer follow-up periods.

Mediated interventions have been shown to be effective with short-term behavior change, and increasing evidence indicates that these approaches may be effective in the longer term. Although print has been studied most extensively, many studies have now demonstrated the efficacy of telephone-based interventions, and studies are under way utilizing the Internet.[88,90,93] Because these interventions rely on little or no face-to-face contact, they are likely to have great reach and favorable cost-effectiveness.

Many individuals who are sedentary also have other unhealthy habits (eg, smoking, poor diet) that increase risk for cardiovascular disease if left unchanged. Although encouraging evidence is emerging with regard to targeting physical activity and other health habits, much more research is needed on whether and how to combine behavioral interventions.

Changing environments to remove barriers to and create opportunities for physical activity for recreational and transportation purposes is a promising new area of research. Limited intervention research has evaluated mainly small-scale environmental changes, such as building trails and signs to promote stair use. Numerous cross-sectional studies demonstrate the promise of major environmental changes, such as creating communities with mixed land use that facilitate active transportation and ensuring that people have easy access to public recreation facilities. Because randomized trials will seldom be feasible with built-environment interventions, priority should be placed on rigorous quasi-experimental evaluations.

In prior decades, physical activity research was largely atheoretical; however, in the last decade, there has been much more focus on the importance of theory.[125] Theories that have been employed most often in intervention research fit under the larger umbrella of SCT or SLT. The transtheoretical model has also been used in numerous intervention studies. Ecological models have expanded the targets of intervention to also include environmental changes. Although theories are now being used in studies, continued work in this area is important, because the field would benefit from studies testing specific hypotheses about what theoretical factors will be changed and at what times during the course of the intervention.

Although physical activity intervention research has grown considerably in the past decade, much work remains to be conducted. Understanding of human biology and behavior continues to grow, but in a disjointed fashion. To integrate and utilize this rapidly growing knowledge base to help promote physical activity, it will be necessary to employ transdisciplinary efforts that are collaborative not only in name but in theory development and hypothesis generation, as well as in study design, implementation, and analysis. Through continued physical activity research, we hope to provide the types of programming and technology that will help individuals to lead more active lives and thereby improve their quality of life.

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CDC indicates Centers for Disease Control and Prevention; VA, Veterans Affairs; NIH, National Institutes of Health; PACE, Patient-centered Assessment and Counseling for Exercise; SD, San Diego; SPARK, Sports, Play, & Active Recreation for Kids; UCLA, University of California at Los Angeles; and CCHMC, Cincinnati Children's Hospital Medical Center.

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