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Increasing physical activity: a quantitative synthesis

[Epidemiology]

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Outline

Graphics

ABSTRACT^

National policy for increasing leisure physical activity in the United States is impeded by a poor understanding of interventions that can be implemented by community and clinical medicine. To clarify the literature in this area, we conducted a quantitative, meta-analysis of 127 studies that examined the efficacy of interventions for increasing physical activity among[almost equal to]131,000 subjects in community, worksite, school, home, and health care settings; 445 effects were expressed as a Pearson correlation coefficient (r) and examined as they varied according to moderating variables important for community and clinical intervention. The mean effect was moderately large, r = 0.34, approximating three-fourths of a standard deviation or an increase in binomial success rate from 50% to 67%. The estimated population effect weighted by sample size was larger, r = 0.75, approximating 2 standard deviations or increased success to 88%. Contrasts between levels of independent moderating variables indicated that effects weighted by sample size were larger when the interventions: 1) employed the principles of behavior modification, 2) used a mediated delivery, 3) targeted groups, 4) of combined ages, 5) sampled apparently healthy people, or 6) measured active leisure, of 7) low intensity, 8) by observation. Independently of sample size, effects were larger when interventions 1) used behavior modification, 2) employed a pre-or quasi-experimental design, or 3) were of short duration, regardless of features of the people, setting, or physical activity. Our results show that physical activity can be increased by intervention. The optimal ways for selecting intervention components, settings, and population segments to maintain increases in physical activity and the relative contributions by community and clinical medicine toward successful physical activity intervention require experimental confirmation, warranting accelerated attention in clinical trials.

Sedentariness is a burden to the public's health in the United States, accounting for an estimated 200,000 deaths annually (45) from coronary heart disease (5,21,31), colon cancer (57), and non-insulin-dependent diabetes (26,30,35). Naturally occurring increases in leisure physical activity (42) or cardiorespiratory fitness (6) are associated with decreased mortality from coronary heart disease and all-causes, whereas regular physical activity is an effective adjuvant for the primary or secondary treatment of hypertension (2,21), obesity (44,58), osteoporosis (20,46), and major depression (17). Moreover, sedentary leisure is highly prevalent (14). Despite national health policy that physical activity be increased (59), best estimates indicate no change in secular physical activity patterns during the past decade (12). Depending upon definition, 25%-60% of U.S. adults are sedentary (12,14,59), just 10%-20% are active enough to increase or maintain physical fitness, while the rest are active sporadically (12,14), with uncertain benefits for health.

The status of physical inactivity in the U.S. is explainable in large part by a limited understanding of interventions available for increasing physical activity. This is true especially in community and clinical medicine, where primary-care physicians and other health care providers have unique opportunities to influence healthful changes in physical activity habits. Although the medical office has priority for implementing physical activity interventions (59), physicians typically report they spend little time counseling patients about exercise (32,36), lacking confidence about their training and abilities to change exercise habits (34,40,55,60,61) even when endorsing the salutary benefits of leisure physical activity for their patients (37,62). Furthermore, the partnership between clinical medicine, which focuses on a patient, and community medicine, which encompasses a population, is poorly defined for guiding interventions to increase physical activity (8,24).

Our purpose for the analysis reported herein is to provide a quantitative synthesis of the literature examining the effects of interventions used to increase physical activity. Our goals are to describe the efficacy of such interventions and the factors that moderate their success in order to guide public health policy, form hypotheses testable by further experimentation, and inform physicians and other health care providers about interventions that increase physical activity in communities and patients.

METHODS^

One-hundred twenty-seven published studies and 14 dissertations were located from 1965 through August, 1995, by computer searches of literature in the English language using *Medline, Current Contents, Psychinfo, SOCIAL SCISEARCH, ERIC*, and *Dissertation Abstracts International* data bases, bibliographic searches, and a personal retrieval system, cross-referenced with expert colleagues. Index words were behavior modification, health promotion, health education adherence, compliance, physical activity, fitness, and exercise. Five redundant publications were excluded. A quantitative synthesis then was conducted using standard meta-analytic procedures (23,25,27,49) with the aid of two statistical software programs: Meta 5.3 (56) and SPSS/PC- 6.0 (39).

Criteria for including a study were: 1) The dependent variable was a measure of physical activity consistent with consensus definitions used in public health (13,43) or a measure of physical fitness that is a surrogate of physical activity (1). 2) The independent variable was an intervention designed to increase habitual physical activity. 3) Outcomes of the intervention were quantified and could be compared with a variance estimate of the outcome from a control group or condition in the absence of the intervention. 4) An effect size could be expressed as a Pearson correlation coefficient r (50), permitting effects to be calculated from studies that used diverse statistical presentations including frequencies, percentages, graphs, *t*-tests, and chi-square- and *F*-tests with a single *df*, when means and standard deviations were not reported (49,50). Sixty located studies were excluded. Commonly used statistical guideposts for evaluating the size of r as a small, moderate, or large effect are 0.10, 0.30, or 0.50 (15,50).

The use of r also permitted a binomial effect size display (51) of the interventions' effects, interpreted as a practical measure of the success of an intervention. An r equaling 0.00 equates to a binomial effect of zero, reflecting a 50% chance for success in the absence of intervention. This approximates the mean success rate of nearly 50% reported for adherence to supervised (19,22) or community-based (54) exercise programs in the absence of intervention. An r of 0.20 is equivalent to an increase in success from 50% to 60%, whereas an r of 0.40 indicates an increase to 70%. When possible, effect sizes were calculated by subtracting the mean change for a control group or condition from the mean change for an experimental group or condition, and dividing this difference by the initial standard deviation of the control scores (15,23). This procedure reduced bias from pooling experimental variance and from the correlated variance of repeated measures (4). For multiple-baseline studies, intervention effects were compared to the initial baseline using the mean of each subject's effects. Interrater agreement for r was determined by intraclass correlation (R_I) computed from ANOVA of r judged by four pairs of raters. Each rater pair blindly retrieved effects from 10 to 15 articles selected separately from among the 127 articles. R_I ranged from 0.89 to 0.96. We also examined variation in effects according to moderating variables deemed practically important for understanding and optimizing effective interventions. Definitions of the moderators are provided in Table 1.

TABLE 1. Moderating variables influencing effects of interventions for increasing physical activity.

TABLE 1. Continued

We retrieved 445 effects from the 127 studies based on [almost equal to]131,156 people. Fisher's z transformation of r (z_r) was used for analyses to adjust for the nonnormal distribution of r, protecting against small sampling bias in estimates of the population r. The reported values of r are back transformations from z. Factors relevant for community and clinical medicine that might moderate the estimated population effect of the interventions were considered by comparing effects among features describing subjects, interventions, settings, and physical activity. Most studies reported multiple effects owing to separate effects derived according to age, race, or gender, concurrent estimates of physical activity using different measures, or follow-up measures of physical activity after an intervention ended. The mean effect was used when a study reported multiple measures of physical activity using the same method (e.g., multiple self-reports). The number of effects and the mean effect size per study were unrelated (r (125) = -0.07, *P* = 0.45), but we adopted a conservative statistical criterion ($P < 0.001$) to protect against Type I error when using several effects per study in analyses of moderators (49,53). Small sample sizes can increase Type II error (25). Hence, individual effects also were weighted by sample size (25,27) to adjust for sampling errors in r, giving more credence to studies with large samples.

RESULTS^

A stem-and-leaf display of the 445 effects is presented in Figure 1, indicating a nearly normal distribution of effects, with a negative skewness. The mean value of r was 0.34 (95% CI, 0.26-0.42), or 0.75 (95% CI, 0.70-0.79) after weighting by sample size. The effect r = 0.34 approximates an effect of three-fourths standard deviation (50). The effects were heterogeneous (49,56). A correlation of 0.25 between sample size and z_r contributed to the larger weighted estimate of r. The corresponding binomial effect represents a potential increase in success rates after intervention from 50% to 67%, or to 88% for the weighted analysis. The estimated population value of r was 0.64, or 0.76 for the weighted analysis, after adjustment (25,27) for a reliability of r = 0.80 among the measures of physical activity (1).

Figure 1-Stem-and-leaf-display for 445 effect sizes (r).

In contrast to results from the published sources, 14 unpublished doctoral dissertations reporting 55 effects for 668 subjects yielded a mean r of 0.17(95% CI, -0.10 to 0.41), or 0.09 (95% CI, -0.18 to 0.35) when effects were weighted by sample size. Hence, we estimated the impact of unpublished null findings upon the population value of r derived from the published studies using the fail-safe *N* (41); a reduction of r to 0.20 from the observed values of 0.34 and 0.75 requires 317 and 1219 null findings, respectively.

Focused contrasts (49,52), each tested as Z at$P < 0.001$, subsequently were conducted to determine if moderators describing subjects, settings, or features of interventions and physical activity important for understanding and implementing interventions in community and clinical medicine might account for variability in the mean effect size. Effects for each moderator are presented in Table 2 as mean r with a 95% confidence interval. Variables that were significant moderators also were entered into a linear multiple regression model to clarify their independent effects for explaining variation in z_r. Moderators with more than two nonordinal levels were dichotomized based on results from the contrasts.

TABLE 2. Moderators of intervention effects (r) weighted or not weighted by sample size. The number of effects for each level is indicated by*N*.

Moderating Variables Weighted by Sample Size^

Subject attributes. Effect sizes did not differ between males and females, between age groups, or between whites and non-whites, but studies that reported on samples combining race or ages reported effects that were larger than those for specific race or age groups. The effect among healthy subjects was larger contrasted with all groups of patients. Small effects were observed in studies of people who had CHD, high risk for CHD, or other chronic diseases or physically or developmentally disabling conditions, but there were relatively few studies of interventions with patients.

Intervention type and setting. Effect sizes differed by intervention type, whereby behavior modification approaches were associated with effects that were larger compared with the other approaches. There were differences according to the manner of delivery of the intervention; effects were larger among studies using mediated approaches contrasted with face-to-face delivery. Interventions in community settings and interventions delivered to groups reported larger effects, contrasted with those in schools and other settings or with delivery to individuals, the family, and to an individual combined within a group, respectively. Effects were larger when the physical activity was not supervised compared with a supervised physical activity program. Effects were unrelated to the number of weeks the intervention, $r(443) = -0.07$, or the follow-up period, $r(171) = -0.06, P > 0.05$, lasted.

Physical activity features. Effect sizes differed according to the mode of physical activity. Effects for active leisure time were larger contrasted with exercise programs prescribing strength, aerobic exercise, or aerobic exercise combined with other fitness activities. Effect sizes did not differ according to the weekly frequency or daily duration, but studies that observed physical activities carried out at a low intensity reported larger effects compared with studies using estimates of physical activities conducted at higher intensities. Effects from studies using an objective measure of attendance or direct observation were larger compared with those using self-reports by participants or surrogate measures of physical activity based on changes in physiological responses to exercise testing or strength. Only about 25% of the studies reported follow-up measures of physical activity to determine if increases in physical activity were maintained after the intervention ended, but followup effects generally were small.

Multiple regression analysis. Direct entry of the significant moderating variables into a multiple linear regression analysis indicated that 9 variables independently accounted for variation in z_r: age, physical activity mode, intervention delivery, health status, physical activity measure, physical activity intensity, social context, intervention type, and research design, $P < 0.05$. Reentry of these variables into the regression model yielded a multiple R of 0.66, adjusted $R^2 = 0.42, F(9,435) = 36.9, P < 0.0001$. Research design did not add to the final model. Results are presented in Table 3.

TABLE 3. Multiple linear regression of effect size z_r on moderator variables (weighted by sample size).

Weighting versus Not Weighting by Sample Size?^

Weighting by sample size yields a better estimate of the true effect of interventions in the population, which is especially important when hypotheses or policy judgments are formed about interventions to increase physical activity in a community. Nonetheless, sampling bias in the relationship between z_r and sample size can create anomalies confounding the interpretation of moderators. Examples presently are the larger effects for samples comprised of several age categories or more than one race in the weighted analysis, contrasted with the small effects for studies that reported separate effects for specific age groups or for whites and non-whites. Numerous studies intervening with large samples did not report analyses separately based on age or race, focusing on mediated approaches with community-based groups participating in unsupervised physical activity of low intensity.

Hence, weighting z_r by sample size can obscure important effects observed in studies of smaller groups of people that may prove to be good estimates of population effects upon further sampling. This concern particularly applies when comparing the effects among interventions applied in clinical health care settings where the mean sample was about 50 people, contrasted with community-based interventions where the mean sample was about 925 people. Several of the aforementioned moderators are important features of clinical applications of physical activity. Thus, additional contrasts were focused on the moderator variables using z_r without weighting by sample size.

Moderating Variables Not Weighted by Sample Size^

Subject attributes. In contrast with the weighted analysis, effects from samples of more than one race did not differ from the effects for specific races. Also, effects from studies sampling patients who were obese or who had developmental or physical disabilities and a chronic illness other than cardiovascular disease were larger than effects of studies of healthy people, all of which were larger than effects from studies of people with, or at risk for, cardiovascular disease.

Intervention type and setting. Behavior modification again had larger effects contrasted with the other interventions. In contrast to the weighted analysis, effects did not differ according to social context, the method of delivering the interventions, or according to the intensity of the physical activity, or whether the physical activity was supervised or free-living without supervision. Also, in contrast to the weighted analysis, effects of interventions conducted in community settings were similar to those applied in home, school, worksite, and health care settings. Effects were related inversely to the number of weeks in the intervention, r (443) = -0.20,$P < 0.001$ and the follow-up, r (171) = -0.18, $P < 0.01$, periods.

Physical activity features. In contrast with the weighted analysis, effects did not differ according to mode or intensity of physical activity. As was the case for the weighted analysis, effects at follow-up generally were small.

Multiple regression analysis. Direct entry of the significant moderating variables into a multiple linear regression analysis indicated that intervention type, intervention length, and research design accounted for variation in z_r, $P < 0.05$. The regression model yielded a multiple R of 0.48, adjusted $R^2 = 0.23$, $F(3,441) = 44.4$,$P < 0.0001$. Health status did not contribute to the model. Results are presented in Table 4.

TABLE 4. Multiple linear regression of effect size z_r on moderator variables (not weighted by sample size).

Research Design^

Effects derived from a pre- or quasi-experimental design (11) ($N = 169$) were larger (mean ± 95% CI (0.87 ± 0.82-0.90 and 0.53 ± 0.41-0.64) than those from randomized experiments ($N = 276$) (0.10 ± 0.00-0.21 and 0.21± 0.09-0.32) in the weighted and unweighted analyses, respectively,$P < 0.001$. Though research design did not independently influence effect size in the weighted analysis, we further examined the impact of lowered internal validity on the moderator analyses by adjusting z_r for the quality of the research design using fractional weights (49) for effects from studies employing a pre- or quasi-experimental design. Contrasts within the moderators then were repeated. The quality of the research design generally did not interact with the moderator variables. Exceptions were that, without weighting by sample size, the studies using pre- or quasi-experimental designs yielded larger effects for low-intensity physical activity and for health care settings, contrasted with the studies using experimental designs, whereas research design in the weighted analysis did not moderate the pattern of effects for physical activity intensity or the intervention setting. Interventions in health care settings, contrasted with those in a community, typically used pre- or quasi-experimental designs, studying supervised physical activity after shorter intervention periods. Otherwise, clinical and community interventions did not differ in the gender, age, or race of subjects or in the features of the interventions and physical activity studied. Hence, the differences in the impact of moderators observed for the weighted vs unweighted analyses were not biased by differing distributions of the moderating variables, but can be partly attributed to the manner by which community versus clinical intervention studies were conducted or reported.

DISCUSSION^

A conservative interpretation of our quantitative synthesis of the literature, gauged by statistical guideposts (15), is that interventions for increasing physical activity have a moderately large effect. The effect also is large practically, equivalent to improving success from the typical rate of 50% without intervention to about 70%-88%(51). Though summaries from a meta-analysis require experimental confirmation, our aforementioned results suggest directions about the best ways to implement effective interventions for increasing physical activity in community and clinical medicine. The analysis of effects weighted by sample size suggests that interventions based on the principles of behavior modification, delivered to healthy people in a community, are associated with large effects, particularly when the interventions are delivered to groups using mediated approaches or when the physical activity is unsupervised, emphasizing leisure physical activity of low intensity, regardless of the duration or frequency of participation. The multiple linear regression model of the moderating variables supported that the larger effects reported for combined ages, behavior modification, and the delivery of the interventions using media, to groups or to healthy subjects, describing low-intensity, active leisure physical activity measured by observation, were independent of each other; whereas the influences on effect size by community setting, combined races, and a pre- or quasi-experimental research design found in the univariate analysis by contrasts were not independent of the other moderating variables.

Since the mean effect for each level of the significant moderating variables was heterogeneous (49,56), interactions among the moderators or their levels will better explain the findings suggested by our independent analysis of moderators. Not all studies reported information on each of the moderators we examined. Hence, there were not enough studies and effects to permit a statistically powerful analysis of interactions among the moderators, a limitation to inferring causality by moderators that is common among meta-analyses.

Our quantitative analysis provides some support for consensus opinions (8,18,28) that modifying traditional guidelines for exercise programming (3) to accommodate moderately intense physical activities of varied types (8,18) in a community using mediated (28), as well as face-to-face, approaches will increase participation among segments of the sedentary population (43). The maintenance of successful physical activity after the conclusion of an intervention has been less encouraging, implying a need for sustained or repeated implementation of interventions. Though past studies have reported little success in increasing physical activity among people representing racial or ethnic minorities or older ages, these groups have been underrepresented in past studies and should receive more attention by researchers in the future.

The aforementioned findings imply an influential role by community medicine for increasing physical activity. Nonetheless, clinical uses of physical activity applied toward the secondary prevention of health problems also are important for public health. When the size of the studies' samples was ignored, interventions in health care settings and schools were similarly effective compared with intervention in the community, regardless of the features of the physical activity. Sample size ignored, interventions were most effective when they employed behavior modification approaches, often combining reinforcement- and stimulus-control. In addition to behavior modification, interventions that altered the physical education curriculum in schools or combined two or more types of interventions were effective. Also, interventions targeting patient groups, other than those with cardiovascular disease or high risk, were more effective compared with interventions targeting apparently healthy people. Though the effects of setting or health status were not independent influences on intervention effectiveness, they warrant experimental testing.

The absence of effects by interventions using health education or health risk appraisals is consistent with a narrative review of the literature (16). In contrast, the apparent ineffectiveness of cognitive-behavior modification and the supervised prescription of moderate exercise is not consistent with previous narrative reviews (18,28). The large confidence intervals surrounding the mean effect, usually including zero, for interventions other than behavior modification, coupled with the smaller number of effects, makes it premature to conclude that interventions other than behavior modification are ineffective for increasing physical activity. This caveat also applies to interventions with heart patients for whom few effects were reported. Also, it appears that interventions other than behavior modification have been implemented in widely varying ways, especially in the case of cognitive-behavior modification. Cognitive-behavior modification techniques often were combined with other interventions, precluding a determination of their independent effects in many studies. These combination interventions had the same effect size as interventions using cognitive-behavior modification, alone. Moreover, most studies using cognitive-behavior modification did not base the interventions on a broader theoretical model of behavior change (29,47).

When weighted by sample size, the effect for pre- and quasi-experimental studies was markedly larger compared with randomized experimental studies, including those using a minimally effective intervention condition (i.e., a placebo). However, a randomized research design is extremely difficult and costly to implement in community- or population-based studies. The use of a placebo for control comparisons was rare, and usually it is not feasible for a population-based study. Scientific quality notwithstanding, whether the research design was experimental versus pre- or quasi-experimental was not an independent influence on the size of effects when weighted by sample size and, ignoring sample size, had little impact on the pattern of moderating effects other than in health care settings, where effects were larger for pre- or quasi-experimental designs. Nonetheless, it is important to not infer prematurely that a moderator implied by our meta-analysis is a casual determinant of variations in effects when the studies we reviewed did not experimentally manipulate levels of the moderator.

Few studies verified self-reported physical activity by measuring increases in fitness expected to result from increased physical activity or by concomitantly using an objective measure of activity such as a motion sensor or observation. While increases in physical activity typically were largest when an objective measure of attendance or observation was used, the failure of interventions to increase physical activity when it was estimated by a surrogate measure of physical fitness indicates that the validity of physical activity measures other than observation remains an important methodology dilemma for the study of physical activity in public health. Furthermore, it is important to determine whether the absolute levels of increased activity were adequate to increase physical fitness (3) or decrease the risk for disease morbidity or all-cause mortality (6,31,42). Only about one-fourth of the studies reviewed herein reported a follow-up to the intervention, but those studies typically showed that increases in physical activity or fitness associated with the interventions were diminished as time passed after the intervention ended. Many of the community studies that reported large effects did not report on the maintenance of physical activity after the intervention's conclusion, or reported a return near to the pre-intervention activity level within a few weeks after the intervention.

Two implications of our literature analysis especially are important for understanding the roles of community and clinical medicine in promoting physical activity. One arises from the larger effects by interventions using media, or applied in large groups, contrasted with smaller effects by interventions to small groups or in a clinical setting, or using face-to-face delivery. Though the larger effects reported in community settings were not independent of the other moderators, the pattern of moderator influences suggested influential roles by public health initiatives and community-based medicine for increasing physical activity. Until around 1990, most intervention studies used single dimensional approaches with small numbers of people of similar gender, race, ethnicity, education, and economic and health status (16,18). More recently, community-based interventions applying psychological and behavioral theories for behavior change have predominated (18,28). These approaches extend beyond the traditional practice of face-to-face counseling to include changes in organizational (community recreation centers, churches, diffusion strategies through schools), environmental (e.g., facility planning), and social (e.g., family interventions) factors or they use cost-effective or convenient vehicles (e.g., mailings, telecommunication) for reaching many people who are not accessible or amenable to traditional interventions based in clinical settings. Such interventions are appropriately part of community medicine, but they do not depend upon a direct physician-patient encounter. They warrant further experimental testing for effectiveness.

Another implication of our analysis is that previous interventions for increasing physical activity applied in health care settings, including cognitive-behavior modification, were not implemented optimally. Our qualitative evaluation of the studies suggests this may be explainable because the studies did not use standardized approaches based on newer theories about how health behavior, specifically physical activity, changes. Recently, a successful clinical trial (10) based in the physician's office used a theoretical model grounded in cognitive-behavior modification (47) that triages patients into stages of readiness for changing their physical activity habits, then introducing standardized counseling by the physician, supported by nurses and staff, that is stage-appropriate. Such an approach offers more promise for increasing physical activity than the counseling approaches traditionally used by physicians (33,36,61) and deserves evaluation by clinically research. About 80% of the U.S. population has annual contact with a physician, with 65% of patient contacts involving primary-care specialities (38). Nearly 50% of practicing physicians in the U.S., about 245,000 physicians, are in primary-care specialities of family or general practice, internal medicine, pediatrics, and obstetrics-gynecology (48) which permit physical activity intervention during patient counseling. Similarly, there are approximately 250,000 nurses in primary care (9) who can support physical activity interventions applied in the medical office. Hence, exploiting more fully the impact of the physician-patient encounter remains an important area for experimental tests of effective interventions for increasing the nation's level of physical activity.

The relative contributions by community and clinical medicine to successful interventions for increasing physical activity warrant accelerated testing by clinical trials. This is important particularly among people with high risk for cardiovascular disease, whereby physical activity exerts its greatest influence in reducing premature death (6,42), yet few interventions for increasing physical activity have been conducted with success in that group. An emphasis also is needed for understanding the ways by which cognitive-behavior modification can be uniformly applied to increase physical activity, since it is theoretically superior to health education, health risk appraisal, and exercise prescription which, though easily implemented, have not proved effective for increasing physical activity.

Controlled experiments are required to confirm the varying effects of interventions suggested by the foregoing analysis and how intervention components, settings, and population segments can be combined to optimally increase and maintain physical activity in the largely sedentary U.S. population. Nonetheless, our quantitative synthesis of the literature demonstrates that the use of behavior modification has efficacy for increasing physical activity, providing a basis for optimism among professionals in public health and medicine that physical activity can be increased.

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EXERCISE; BEHAVIOR MODIFICATION; INTERVENTION; PREVENTIVE MEDICINE; PUBLIC HEALTH

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