Interventions to Increase Physical Activity Among Aging Adults: A Meta-Analysis

Vicki S. Conn, Ph.D., R.N.
School of Nursing
University of Missouri-Columbia

Jeffrey C. Valentine, Ph.D. and Harris M. Cooper, Ph.D.
Department of Psychological Sciences
University of Missouri-Columbia

ABSTRACT

Objectives: This review applied meta-analytic procedures to integrate primary research findings that test interventions to increase activity among aging adults. Methods: We performed extensive literature searching strategies and located published and unpublished intervention studies that measured the activity behavior of at least five participants with a mean age of 60 years or greater. Primary study results were coded, and meta-analytic procedures were conducted. Results: The overall effect size, weighted by sample size, was $d_w = .26 \pm .05$*. Effect sizes were larger when interventions targeted only activity behavior, excluded general health education, incorporated self-monitoring, used center-based exercise, recommended moderate intensity activity, were delivered in groups, used intense contact between interventionists and participants, and targeted patient populations. Effect sizes were larger for studies that measured exercise duration and studies with a time interval of less than 90 days between intervention and behavior measurement. Conclusions: These findings suggest that group-delivered interventions should encourage moderate activity, incorporate self-monitoring, target only activity, and encourage center-based activity. Findings also suggest that patient populations may be especially receptive to activity interventions. Primary research testing interventions in randomized trials to confirm causal relationships would be constructive.*

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INTRODUCTION

Physical activity levels among older adults remain low despite the documented health benefits of activity (1–6). Healthy People 2010 objectives call for a dramatic increase in the number of elderly people who engage in physical activity. Lack of activity may be explainable in part by limitations in professionals' and researchers' understandings about what constitutes an effective activity promotion intervention (7). Recently, research addressing this issue has expanded and with that expansion comes the need to synthesize and integrate the research findings. This quantitative synthesis was designed to meet that need.

Previous narrative reviews of studies testing interventions to increase aging adults' activity have identified unresearched topics but generally have provided little synthesis of findings (8,9). In addition, no quantitative reviews have been conducted that have focused on older adults. Dishman and Buckworth reported a meta-analysis of interventions to increase physical activity among adults of all ages (7). They reported larger effect sizes in preexperimental or quasiexperimental designs and when interventions (a) used behavior modification principles, (b) used mediated delivery, (c) were delivered in group and community, (d) encouraged unsupervised active leisure physical activity, (e) sampled nonpatient populations, (f) measured low-intensity activity, and (g) used observational activity measures. Effect sizes were unrelated to the number of weeks of intervention. Only 3 of the 43 studies focusing on aging adults in this meta-analysis were included in Dishman and Buckworth's meta-analysis of youth and adults of all ages (7).

Several questions remain regarding the effectiveness of interventions to increase activity among aging adults. This synthesis furthers understanding of interventions to increase physical activity among aging adults by examining the following questions:

1. What is the overall effect of interventions on physical activity behavior?
2. Does the effect of interventions vary depending on the type of intervention?
3. Does the effect of interventions vary depending on participant attributes?
4. Does the effect of interventions vary depending on study design characteristics?

METHODS

Sample

Inclusion criteria. The presence of an explicit intervention to increase physical activity behavior was required for inclusion. Intervention was defined as a planned and systematically applied set of actions, delivered at a specified site and time, designed to elicit physical activity behavior change among persons exposed to the intervention (10). The experimental group was considered the participants who received the most intensive intervention, and the control group received usual care or some form of attention. If a single study contained two intervention groups and no control group, then each group was coded as a one-group pretest posttest design study. For example, Bocksnick tested interventions in two experimental groups. One group received written exercise change motivational materials and

Reprint Address: V. Conn, Ph.D., R.N., S317 School of Nursing, University of Missouri, Columbia, MO 65211. E-mail: conn@missouri.edu

performed weekly self-monitoring and the other group received exercise counseling in addition to the motivational materials and self-monitoring intervention components (11). This management of studies with two treatment groups and no control groups was necessary because no studies replicated comparisons between treatment groups.

Studies with adequate reported information for extraction of effect sizes were included if they met the following criteria:

1. Mean age of participants was 60 years or greater.
2. The study contained a minimum of 5 participants.
3. Data were reported during the years 1960 through 1999.
4. The study examined overall physical activity (total amount of body movement) or episodic exercise behavior (structured repetitive large muscle movement) as an outcome variable.
5. The research report was in English.

We included small sample studies because it is important to summarize the broad scope of studies that have been conducted. Often these studies have inadequate statistical power to detect treatment effects. Our analysis plan weighted studies such that those with larger samples had proportionally more impact on overall effect size calculations. We included both published and unpublished studies in our analysis for two reasons (12). First, including unpublished studies allowed us to include a richer variety of interventions for increasing activity among the elderly. Second, because the single biggest difference between published and unpublished research is the statistical significance of the results, meta-analyses that only include published studies are likely to overestimate the magnitude of the true population effect (13).

Because withholding treatment may pose ethical problems in studies with patient populations, studies without control groups were included if they contained the predata and postdata needed to extract an effect size (14). When multiple research reports described results at different intervals following the intervention, the report using the longest duration of follow-up was included in the review (15). The most distal data collection point was selected because enduring behavior will be more likely to meet public health goals.

Research reports limited to flexibility or muscle strengthening exercise were excluded (16). Studies with persons institutionalized for mental health problems were excluded (17). Other studies were excluded when it was not clear whether the intervention of providing exercise classes was included in the measure of the dependent variable or the measure of physical activity was participation in an intervention designed to have positive health benefits (18–20). Studies using health or fitness as the only outcome measures were excluded because these indirect measures are influenced by factors besides behavior.

Literature search strategies. Multiple search strategies were employed to enlarge the scope of studies retrieved beyond those identified in previous reviews and thus limit the bias introduced by narrow searches (21). Computerized search strategies are presented in Table 1. Previous review articles on physical activity interventions for other populations and potential primary study bibliographies were examined (8,9,22,23). Computerized searches were conducted on all authors of retrieved studies meeting the inclusion criteria. Finally, senior authors were contacted by e-mail to solicit additional research reports.

Procedure and Analysis

A coding frame was developed to assess four categories: source characteristics, participant characteristics, experimental characteristics, and primary study results. Source characteristics included publication vehicle (e.g., journal article or dissertation) and year of publication. Participant characteristics included age, gender, and health criteria used for inclusion in the primary study (e.g., arthritis). Experimental characteristics were coded that describe both the study design (e.g., randomization) and the intervention.

Three design features that are particularly important in this area of research were coded. The time interval between intervention completion and outcome variable measurement is an important methodological difference because exercise behavior decays rapidly during the first 6 months after initiating an exercise program. A second important feature was the presence or absence of random assignment in studies with treatment and comparison groups. Several studies used comparison groups that were assigned by geography or other nonrandom means. Some studies examined only single treatment groups without any comparison groups. These important design features were coded to enable us to examine the impact of these features on effect sizes and to control for effects in analysis of other potential moderating variables. Outcome measure features were coded as well. These included activity duration per session, frequency of exercise sessions per week, and activity intensity. Some composite measures assessed multiple dimensions.

An explicit description of each intervention component was developed, piloted, revised, and implemented to categorize intervention elements. Interventions could include motivational content, supervised center-based exercise, or both. The motivational intervention components are briefly summarized in Table 2. Cognitive and behavior modification categories were coded whenever the research report specifically used these phrases or when components typically associated with these behavior change strategies were reported. We analyzed the data and examined both these two broad categories and each specific behavior change strategy. General health education was coded whenever reports described their intervention in these terms or when the authors noted that they taught health benefits of exercise. Other aspects of the trials were coded, such as whether the researchers recommended identical forms or intensities of exercise to all members of the treatment group. Some studies specifically recommended that participants walk as exercise. Aspects of the interventions that were independent of the nature of the content were also coded. Interventions were coded as being delivered to groups if the predominant contact between the interventionist and participants was in a multiple participant setting, for either supervised

TABLE 1
Computerized Search Strategies

		Search		
Source	*Dates*	*Strategy*	*First Concept*	*Second Concept*
Dissertation Abstracts	1966–1999	Title, abstract, heading word	Exercise or physical activity	and Intervention or program or promote or promotion oradherence or compliance
National Library of Medicine MEDLINE	1966–1999	Title, abstract, mesh heading, registry word	Exercise or exertion or exercise therapy or physical education and training or physical fitness or walking	and Health behavior or patient compliance or patient education or health promotion or health education or behavior therapy or life style or preventive health services or program evaluation or evaluation studies or outcome and process assessment or intervention studies or treatment outcome
Cumulative Index to Nursing & Allied Health (CINAHL)	1982–1999	Title, CINAHL subject heading, abstract	Exercise or exertion or exercise therapy or physical education and training or physical fitness or walking	and Health behavior or patient compliance or patient education or health promotion or health education or behavior therapy or life style or preventive health services or program evaluation or evaluation studies or outcome and process assessment or intervention studies or treatment outcome
PsycINFO	1967–1999	Title, abstract, heading, table of contents, key phrase	Exercise or activity level or walking or physical fitness	and Health behavior or health promotion or health education or behavior change or behavior therapy or cognitive therapy or positive reinforcement or program evaluation or self management or illness behavior or prevention or preventive medicine or treatment compliance
American Association of Retired Persons' Ageline	1978–1999	Title, abstract, descriptor	Exercise or physical activity	and Intervention or outcome or promotion or program evaluation or outcomes or intervention strategies or compliance or adherence or trial or impact or dropout
SPORT Discus	1970–1999	Abstract, subject, heading, title, English classification	Exercise or fitness or physical activity	and Intervention or outcome or random or trial or impact or compliance or noncompliance or adherence or success

exercise or motivational content. Studies that recommended participants exercise at home were coded as home based and those that provided an exercise center were coded as center based. To establish reliability of coding, the first author and a research assistant coded a set of research reports and resolved disagreements. All studies were coded by the first author.

A standardized mean difference, or *d* index, was calculated for the sample (24). This metric allows expression of the difference in postintervention activity scores between the treatment and control group, or pretest scores if control groups were not used, regardless of the metric of the test itself. The mean difference between experimental and control groups divided by the pooled

TABLE 2

Intervention Components Coded for the Meta-Analysis

Category	*Description*
Behavioral modification	Code when this phrase is used to describe intervention components or theory. Also code this if mentions stimulus control, self-monitoring, consequence management/rewards/reinforcement, or contracting.
Cognitive modification	Code when this phrase is used to describe intervention components or theory. Also code this if mentions thought restructuring, decisional-balance activities, goal setting, relapse prevention education, or self-management education.
Commitment[a]	Activities specifically described as intending to increase commitment (e.g., making a private commitment to self and then announcing to others your decision; decision-making therapy, New Year's resolutions); code only when does NOT fit with contracting, goal setting, or decision balance categories.
Consequences/reinforcement/rewards[a]	Using specific preplanned tangible or intangible positive consequences of exercise behavior (e.g., lottery, praise, token economy, competition that has a reward, contracting for a reward).
Contracting[a]	Written contracts or agreements about exercise behavior (use only if a reward is *not* part of the contract; if a reward is mentioned code as consequence control).
Decisional balance[a]	Activities in which advantages and disadvantages of behavior are deliberately considered (e.g., decision balance sheets).
Exercise at a center	Participants exercise in a particular location at a specified time under the supervision of research staff.
Exercise prescription	Individualized specific exercise form/intensity suggested to participants.
Feedback[a]	Provide information to participants about their exercise behavior (use only if the feedback was not part of consequences/rewards).
Fitness testing[a]	Test the physical fitness of each participant as a component of the intervention.
Goal setting[a]	Written or oral goals (not used if there is a contract with someone else or if there is a reward associated with achieving the stated behavior).
Health education	Provision of information with main focus on inactivity risks and exercise benefits (only coded if specifically stated that this information was provided or if they described providing education about exercise in relationship to particular disease processes).
Health risk appraisal[a]	Specific researcher-provided assessment of risks of major illness that can be altered by exercise behavior, code only if the report describes this information as health risk appraisal.
Relapse prevention training/education[a]	Code if this phrase is used.
Self-management[a]	Code when this phrase is used but no further specification is provided.
Self-monitoring	Participant recording of physical activity/exercise as an intentional component of the intervention (not coded if intermittent recordings used for data collection).
Social modeling	Opportunities to watch similar others exercise.
Social support	Use if explicitly states social support.
Stimulus control[a]	Modification of the environment to cue exercise behavior (e.g., prompts, cues, signs, posters, telephone prompts).
Thought restructuring[a]	Teaching altered ways of thinking about exercise-related phenomenon (e.g., coping self-statements; new statements about failure); do not code as "thought restructuring" if this is a component of relapse prevention education.

[a]Motivational component coded but insufficient numbers of primary studies with the component for moderator analysis.

standard deviation was used when available. Other data that can be converted to *d* index values using standard meta-analytic procedures were used when mean differences were not reported. For example, a *d* index can be computed when a primary study reports the value of the *t* or *F* test associated with a comparison between experimental and control groups (25). Weighted effect sizes were calculated by multiplying each effect size by the inverse of its variance, which gives larger samples more weight in the effect size estimates. Calculation of 95% confidence intervals for weighted estimates was used to test the average *d* index for significance. The unit of analysis was the independent samples' physical activity data. Four research reports each contributed two independent effect sizes for the meta-analysis; the remaining 35 reports each contributed one effect size.

We conducted homogeneity analysis to look for the presence of moderating variables (25). Homogeneity analyses compare the amount of variability in an observed set of effect sizes with the amount of variance that would be expected by sampling error alone. The subgroup analysis looking for moderating variables was conducted when there were at least 10 cases in each subgroup and there were no more than three times the number of cases in the largest subgroup as there were in the smallest subgroup.

Both the overall analysis and the moderator analyses were carried out using the random effects model (25). The random effects model assumes that individual effect sizes are composed of two sources of error: (a) participant-level sampling error and (b) other sources of study-level error (e.g., variations in settings and procedures). In essence, the random effects model treats any given implementation of a study as a random observation from a population of studies that could have been conducted and is particularly appropriate when study implementation is heterogeneous (as was the case in our meta-analysis) (26). The random effects variance component was calculated using the noninterative method of moments technique (27). Effect sizes (d_{wc}) mentioned in the text are based on the random effects model weighted for sample size and controlled for methodological differences, unless otherwise specified.

RESULTS

Forty-three (N = 43) studies with 33,090 participants met the inclusion criteria and were incorporated in the meta-analysis (included studies are indicated by an asterisk in the reference list) (11,15,28–65). Comparisons between treatment and control groups at outcome data collection were used when available. Single treatment group preintervention and postintervention scores were compared only when comparison group data were not available. The overall effect size, weighted by sample size, was $d_w = .26 \pm .05$. Thus, the null hypothesis that interventions designed to increase activity do not affect activity among older adults can be rejected. The magnitude of the effect is small (small = .20; moderate = .50; large = .80). This effect size is associated with a U_3 value of 60%, which means that 60% of the people in the treatment group had higher physical activity scores than did the average person in the control group (66).

A homogeneity analysis ($Q_t = 86.38$, $df = 42$, $k = 43$) documented that the variance in effect sizes significantly differed from that expected by sampling error alone. Therefore, we conducted follow-up searches for moderating influences on the effect sizes.

Moderator Analysis

To create d index estimates that were uncorrelated with evaluation design features, we decided to control for three features of evaluation design: (a) whether the study used random assignment, (b) the length of the delay between the end of the intervention and the measurement of the outcome variable, and (c) whether the study used a one-group pretest–posttest design or a two-group design. These three variables were entered into a regression equation simultaneously. The residuals from the regression were then used as described as follows but, because the residuals have an average value of 0, we first added .26 (the average of the weighted d values). The results of subsequent analysis testing for moderators are presented in Tables 3 and 4.

Experimental characteristics—methodology. This analysis examined the impact of design considerations on effect sizes

TABLE 3

Random Effects Model Subgroup Analysis Testing Methodology, Source, and Participant Variables

			Uncontrolled[a]			*Controlled*[b]		
Variable	*Level*	*n*	*Weighted* d_w	*95% CI*	*p*	*Weighted* d_w	*95% CI*	*p*
Methodology								
Outcome measure	< 90 days	16	.42	.16	< .05	n/a		
	>180 days	13	.22	.12				
Random assignment	Absent	25	.28	.11	*ns*	n/a		
	Present	18	.37	.13				
Pre–post design	Present	29	.34	.10	*ns*	n/a		
	Absent	14	.26	.14				
Duration measured	Absent	19	.25	.10	< .01	.25	.11	< .05
	Present	23	.39	.10		.38	.10	
Frequency measured	Absent	14	.23	.11	*ns*	.26	.12	*ns*
	Present	28	.38	.12		.34	.10	
Intensity measured	Absent	26	.35	.10	*ns*	.34	.11	*ns*
	Present	16	.23	.10		.25	.10	
Source and participant characteristics								
Journal publication	Absent	13	.43	.16	*ns*	.37	.20	*ns*
	Present	30	.30	.10		.30	.08	
Only aged adults	Absent	23	.33	.10	*ns*	.34	.10	*ns*
	Present	20	.32	.15		.30	.13	
Patient sample	Absent	25	.24	.11	< .05	.26	.10	< .05
	Present	18	.42	.12		.39	.12	

Note. N = 43. d_w = effect size weighted by sample size. Comparisons between treatment and control groups at outcome data collection were used when available. When necessary preintervention and postintervention scores were compared. d_{wc} = effect size weighted by sample size and controlling for design features. CI = confidence interval.

[a]Weighted by sample size. [b]Weighted by sample size and controlled for random assignment, pre–post design, and timing of dependent variable measurement.

TABLE 4
Random Effects Model Subgroup Analysis Testing Possible Intervention Moderating Variables

			Uncontrolled[a]			*Controlled*[b]		
Variable	*Level*	*n*	*Weighted* d_w	*95% CI*	*p*	*Weighted* d_{wc}	*95% CI*	*p*
Theory based	Absent	28	.26	.08	*ns*	.28	.08	*ns*
	Present	15	.28	.12		.25	.13	
Health education	Absent	11	.59	.16	< .001	.59	.17	< .001
	Present	30	.27	.10		.26	.09	
Exercise prescription	Absent	24	.26	.10	*ns*	.27	.09	*ns*
	Present	17	.42	.17		.40	.16	
Behavior modification	Absent	26	.30	.10	*ns*	.31	.10	*ns*
	Present	17	.37	.16		.34	.14	
Self-monitoring	Absent	27	.29	.10	< .01	.30	.10	< .01
	Present	14	.47	.14		.39	.14	
Cognitive modification	Absent	31	.36	.10	*ns*	.34	.10	*ns*
	Present	12	.24	.14		.25	.13	
Social modeling	Absent	29	.47	.10	*ns*	.33	.09	*ns*
	Present	12	.35	.18		.28	.20	
Social support	Absent	30	.32	.10	*ns*	.31	.09	*ns*
	Present	11	.32	.22		.29	.21	
Intense contact with interventionists[c]	Absent	14	.19	.08	< .01	.19	.12	< .01
	Present	14	.40	.10		.44	.13	
Exercise at center vs. home exercise[d]	Absent	28	.24	.10	< .001	.24	.08	< .01
	Present	15	.49	.16		.47	.16	
Recommend walking as exercise form	Absent	32	.30	.09	ns	.29	.10	*ns*
	Present	11	.40	.22		.40	.18	
Specific exercise intensity recommended	Low	13	.27	.15	< .01	.26	.14	< .01
	Moderate	10	.58	.17		.58	.17	
Recommend any intensity level	Absent	20	.21	.10	< .05	.25	.10	< .05
	Present	23	.39	.12		.39	.12	
Target exercise behavior only[e]	Absent	15	.21	.11	< .01	.23	.12	< .01
	Present	18	.41	.12		.38	.11	
Mediated delivery (telephone, mail)	Absent	31	.28	.12	*ns*	.27	.11	*ns*
	Present	12	.20	.10		.21	.10	
Delivered to group of participants	Absent	18	.23	.10	< .05	.22	.09	< .05
	Present	23	.37	.13		.37	.12	

Note. $N = 43$. d_w = effect size weighted by sample size; d_{wc} = effect size weighted by sample size and controlling for design features; CI = confidence interval.

[a]Weighted by sample size. [b]Weighted by sample size and controlled for random assignment, pre–post design, and timing of dependent variable measurement. [c]Tested as a continuous variable, but reported effect sizes based on a median split for ease of interpretation. [d]Exercise at a centralized location designed as an exercise facility. [e]Intervention aimed exclusively at exercise behavior (as compared to those focused on multiple health behaviors).

(Table 3). These effect sizes were weighted by sample size (d_w). The length of the interval between completing the intervention and measuring activity behavior was associated with significantly different effect sizes. Studies using less than 90 days had an average effect size of $d_w = .42 \pm .16$ ($k = 16$) compared with studies with more than 180 days with an average effect size of $d_w = .22 \pm .12$ ($k = 13$). The difference in effect sizes for studies that randomly assigned participants and studies that did not was not significant. No statistically significant differences were found between effect sizes of pre–post designs and other designs. The remainder of the analyses controlled for all three design features.

Most studies ($n = 32$) measured only one or two of the three dimensions of exercise (intensity, frequency, and duration). Studies including a measure of exercise duration as an outcome variable (Table 3) reported larger effect sizes ($d_{wc} = .38 \pm .12$, $k = 23$) than studies without a duration measure ($d_{wc} = .25 \pm .10$, $k = 19$). The difference between studies measuring exercise frequency and those without that measure was not statistically significant. A similar nonsignificant difference was found between studies measuring exercise intensity and those not measuring intensity.

Source and participant characteristics. Seventy percent ($n = 30$) of the studies were reported in journal articles; the remainder were unpublished graduate theses and dissertations. No statistically significant differences in effect sizes were observed between journal articles and unpublished graduate research projects.

Mean participant ages in the primary studies ranged from 60 to 77.2 years. There was no statistically significant difference in effect sizes between samples comprised entirely of older adults and studies that included some younger adults (Table 3). Sixty-two percent of the participants were female among the studies reporting gender distribution. Moderator analysis of gender's association with effect sizes was not conducted because only 5 studies reported more male than female participants. Only 10 studies reported ethnic composition; 81% of their participants were White. Some studies targeted particular patient populations such as cardiac patients ($n = 4$), people with arthritis ($n = 3$), those visiting primary care ($n = 3$), overweight individuals ($n = 2$), and people with diabetes ($n = 2$). Most studies did not target patient populations with particular health problems ($n = 25$). Studies with patient samples reported significantly larger effect sizes ($d_{wc} = .39 \pm .12$, $k = 18$) than studies with nonpatient samples ($d_{wc} = .26 \pm .10$, $k = 25$).

Experimental characteristics—interventions. Theoretical frameworks guiding intervention development were explicitly stated or clearly apparent in only 15 studies. The presence of a theoretical framework was not associated with larger effect sizes (Table 4). The most common framework was social cognitive theory ($n = 6$) followed by the transtheoretical model ($n = 3$) and cognitive behavioral theory ($n = 2$). Less-often cited frameworks included Kanfer's self-control model, Pender's health promotion model, the social marketing model, and one intervention based on developmental principles. Insufficient numbers of primary studies were based on any one theoretical framework to allow a comparison of effect sizes based on the presence or absence of each framework.

Several intervention components were reported by 10 or more studies, which allowed examination of differences in effect sizes between studies using that intervention component and the remaining intervention studies. The most common intervention was general health education ($n = 30$), which included providing information about the benefits of exercise. The presence of health education was associated with lower effect sizes ($d_{wc} = .26 \pm .09$, $k = 30$) than the comparison subset that did not include general health education in the intervention ($d_{wc} = .59 \pm .17$, $k = 11$).

Exercise prescription ($n = 17$) and behavior modification strategies ($n = 17$) were the next most common intervention components. The presence of exercise prescription was not associated with statistically higher effect sizes than studies without exercise prescription. Behavior modification included studies self-labeled as behavior modification and studies that used contracting, managing consequences (e.g., planned rewards), shaping (rewarding successive approximations changing toward the desired behavior), managing stimuli to cue exercise behavior, and self-monitoring exercise behavior. There were no statistically significant differences in effect sizes based on the presence of behavior modification. One behavior modification strategy, self-monitoring, contained enough primary studies to justify an analysis of that intervention component. Studies testing interventions using self-monitoring reported larger effect sizes ($d_{wc} = .39 \pm .14$, $k = 14$) than studies without self-monitoring ($d_{wc} = .30 \pm .10$, $k = 27$).

Cognitive modification was reported by 12 studies and included strategies of teaching self-management, self-reevaluation activities, thought restructuring, decisional balance activities (weighing advantages and disadvantages of exercise), relapse prevention training, and goal setting. Effect sizes of studies with cognitive modification were not significantly larger than studies without cognitive modification. Social modeling, the opportunity to watch similar others exercise, was present in 12 studies. Social support, including team building, group enhancement, and active behaviors to implement social support, was present in 11 studies. The presence or absence of social modeling or social support was not associated with statistically significant differences in effect sizes (Table 4).

Some interventions included only motivational components whereas others included supervised exercise. There was a significant relationship between the level of program intensity and the effect size. Intensity was defined by the minutes of contact between research interventionists (including any supervised exercise time) and participants. Reports based on programs that featured relatively high levels of program intensity had higher effect sizes ($d_{wc} = .44 \pm .13$, $k = 14$) than did reports based on programs that featured relatively low levels of program intensity ($d_{wc} = .19 \pm .12$, $k = 14$). Intensity of contact between interventionists and participants was used as a moderator instead of length of the interventions because interventions of similar length sometimes varied dramatically in intensity. For example, one study had two intervention episodes spread over 1 year, whereas another study had multiple intervention episodes every week over 1 year (30,48).

Most studies used home-based activity; 15 used center-based exercise. Center-based exercise was conducted at centralized locations designed as exercise facilities. Studies testing center-based exercise reported significantly larger effect sizes ($d_{wc} = .47 \pm .16$, $k = 15$) than studies with home-based exercise ($d_{wc} = .24 \pm .08$, $k = 28$). There was not a statistically significant difference in effect sizes between studies recommending walking exercise and those without that specific recommendation. Low-intensity exercise was suggested for participants in 13 studies, and moderate-intensity exercise was suggested for participants in 10 studies. Studies recommending moderate-intensity activity reported significantly larger effect sizes ($d_{wc} = .58 \pm .17$, $k = 10$) than interventions recommending low-intensity activity ($d_{wc} = .26 \pm .14$, $k = 13$). Interventions that made any recommendation regarding intensity recorded larger effect sizes ($d_{wc} = .39 \pm .12$, $k = 23$) than interventions without an intensity recommendation ($d_{\mathrm{wc}} = .25 \pm .10$, $k = 20$).

Most studies ($n = 28$) tested interventions designed to change only activity behavior; the remainder addressed activity plus diet, other health behaviors, or both. Studies testing interventions targeted only at activity behavior reported higher effect sizes ($d_{\mathrm{wc}} = .38 \pm .11$, $k = 18$) than studies designed to change multiple health behaviors ($d_{\mathrm{wc}} = .23 \pm .12$, $k = 15$). Insufficient numbers of primary studies tested alternative modes of intervention delivery (mail, $n = 7$; telephone, $n = 4$; or mass media, $n = 2$)

besides face-to-face delivery to allow statistical comparisons between each form of mediated delivery. A subgroup comparison between studies without mediated delivery and those with any form of mediated transmission revealed similar effect sizes. Interventions delivered to individuals resulted in smaller effect sizes (d_{wc} = .22 ± .09, k = 18) than interventions delivered to researcher-formed groups (d_{wc} = .37 ± .12, k = 23).

DISCUSSION

These findings document that aging adults' physical activity behavior is amenable to intervention. The modest overall effect size suggests that challenges remain in designing interventions that are effective with more elders and that are successful in attaining larger changes in activity behavior among those who increase their activity.

The effect size calculated from these primary studies was smaller than Dishman and Buckworth reported (7). Study differences could account for the smaller effect size. Dishman and Buckworth incorporated adults of all ages, and few of their primary studies focused on older adults. Only three studies were included in both meta-analyses. It is plausible that it is more difficult to increase physical activity among aging adults. Perhaps the more important distinction between the meta-analyses is that Dishman and Buckworth noted that only one fourth of their primary studies included behavior measurement after interventions were complete (7). They noted these effects were small but did not report specific values. Most studies in this meta-analysis collected outcome data after completion of the interventions, a mean of just more than 300 days following the interventions. The difference in effect sizes probably reflects the well-documented decline in behavior following intervention completion (28,61). Unfortunately, few studies measured outcomes immediately after the intervention and at distal data collection points. Fewer than one fourth of the primary studies in this meta-analysis reported multiple outcome data collection points. More primary studies with multiple outcome assessments are needed to examine interventions that most effectively initiate behavior change as well as those most likely to result in enduring physical activity. Future research testing both the immediate effects of interventions as well as the long-term changes in activity behavior is essential to meet public health goals.

The finding that effect sizes were larger for patient populations is interesting. Dishman and Buckworth reported larger effect sizes for nonpatient participants (7). They reported retrieving few studies targeting individuals with particular health problems. This is probably a difficult literature to access. Patient populations are important segments of the population because increasing activity may lead to valuable secondary and tertiary prevention outcomes. The finding of larger effect sizes for patient populations suggests a window of opportunity, or teachable moment, for these individuals. Further work synthesizing results within disease or patient groupings and across groupings is needed. Whether interventions to increase activity need to be distinct for different patient populations remains an empirical question.

These findings suggest some directions for designing activity behavior change programs. The intensity of the intervention, in terms of amount of contact time between interventions and participants, is probably important. Further primary research is needed to determine the ideal amount of intervention contact. This synthesis supports the inclusion of self-monitoring in activity behavior change interventions. General health education is often the main ingredient in health behavior change interventions. The findings with interventions that contain health education reporting smaller effect sizes than interventions without health education challenge this conventional wisdom. It is possible that omitting general health education from the intervention caused researchers to focus more effort on developing the motivational components. The findings suggest that general health education should be a secondary concern in designing interventions to increase activity. These findings support making specific intensity recommendations to aging adults and ideally to engage in moderate activity.

Several intervention components were associated with effect sizes nearly identical to or smaller than those of studies without that component. These components of questionable value for aging adult populations include cognitive modification, social modeling, and social support. Other intervention components probably could benefit from further testing because sizable differences did not achieve statistical significance, perhaps because of the limited number of primary studies. These include prescribing exercise, modifying behavior, and recommending walking as the form of activity. Further research is needed to test specific components found too infrequently for meaningful comparison in this synthesis (e.g., contracting, decisional balance activities, feedback, fitness testing, goal setting, stimulus control). Although health promotion programs often target multiple behaviors, our findings suggest that interventions focused exclusively on activity may be more effective for aging adults. Intervention delivery to groups, versus individuals, is consistent with both our findings and those reported by Dishman and Buckworth (7). The larger effect sizes found for center-based exercise were unanticipated because Dishman and Buckworth reported larger effect sizes for home-based than center-based activity. Many older adults have more time available to attend group exercise sessions. Older adults who live alone may find the structured time with others motivating and satisfying. Although center-based activity is more expensive than home-based activity, potential health gains may justify the resources. Further research comparing home-based and center-based activity and variations on center-based activity with younger and older adults would be helpful.

Physical activity interventions based on social cognitive theory and the Transtheoretical Model are now common. Meta-analysis may contribute to our understanding of the ability of interventions based on these frameworks to increase activity as sufficient numbers of primary studies become available. Limitations in primary studies narrow the review-generated evidence available through meta-analysis (12). Many attributes of interventions were too frequently found to allow meta-analytic techniques to synthesize this information. Some differences in effect sizes were of considerable size but not statistically different because of the amount of variability related to the small number of primary studies. Further primary research is essential to allow meta-analytic reviews to determine if these components increase activity among aging adults. Unfortunately, many studies continue to exclude elders or not report results for included older adults (8,67). Clear conceptualizations regarding overall physical activity and episodic exercise for both intervention design and outcome measurement are essential to move understanding forward.

This meta-analysis examined endurance exercise. Recently, considerable attention has focused on the positive health benefits of strengthening and flexibility exercise (68,69). These forms of exercise are conceptually distinct from endurance exercise and thus were not included in the synthesis. When sufficient primary studies exist that test interventions to increase flexibility and strengthening exercise, a similar meta-analysis across intervention trials should be conducted.

The amount and nature of the extant primary studies limit definitive answers to many important questions about interventions to increase physical activity among aging adults. For example, it would be valuable to have sufficient studies to conduct moderator analysis on the predominant gender and ethnicity of the samples, specific chronic illnesses such as arthritis or heart disease, and the social context of intervention delivery. Further, limitations in the reporting of primary studies present challenges for synthesis. Findings about intervention categories must be interpreted with caution because primary reports often provide little detail about interventions. The amount of time allocated to intervention components, quality of intervention delivery, and content validity of interventions are important intervention dimensions that may strongly affect outcomes (10). Primary studies generally contain insufficient information to evaluate this aspect of the interventions. Unfortunately, many reports do not provide information about dropout, another important problem in longitudinal intervention research. These limitations affect the interpretation of individual primary studies by other researchers as well as attempts to synthesize findings through meta-analysis.

Overall, the data support the potential efficacy of interventions to increase activity among aging adults. Challenges remain in developing interventions that are effective in promoting larger changes in activity behavior among more elders. The potential gains in health and well-being following increases in physical activity justify continued research. Controlled experiments that test variations in intervention components and delivery are urgently needed to forward our understanding of effective strategies to change activity behavior.

REFERENCES

References indicated by an asterisk are included in the meta-analysis.

(1) Geffken DF, Cushman M, Burke GL, et al.: Association between physical activity and markers of inflammation in a healthy elderly population. *American Journal of Epidemiology.* 2001, *153:*242–250.

(2) Mazzeo RS, Cavanagh P, Evans WJ, et al.: American College of Sports Medicine position stand: Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise.* 1998, *30:*992–1008.

(3) NIH Consensus Development Panel on Osteoporosis: Osteoporosis prevention, diagnosis, and treatment. *Journal of the American Medical Association.* 2001, *285:*785–795.

(4) Paw MJ, de Johng N, Pallast EG, et al.: Immunity in frail elderly: A randomized controlled trial of exercise and enriched foods. *Medicine & Science in Sports & Exercise.* 2000, *32:*2005–2011.

(5) Unger JB, Johnson CA, Marks G: Functional decline in the elderly: Evidence for direct and stress-buffering protective effects of social interactions and physical activity. *Annals of Behavioral Medicine.* 1997, *19:*152–160.

(6) Vandervoot AA: Functional and metabolic consequences of sarcopenia. *Canadian Journal of Applied Physiology.* 2001, *26:*90–101.

(7) Dishman RK, Buckworth J: Increasing physical activity: A quantitative synthesis. *Medicine & Science in Sports & Exercise.* 1996, *28:*706–719.

(8) Dunn AL, Andersen RE, Jakicic JM: Lifestyle physical activity interventions: History, short- and long-term effects, and recommendations. *American Journal of Preventive Medicine.* 1998, *15:*398–412.

(9) Marcus BH, Owen N, Forsyth LH, Cavill NA, Fridinger F: Physical activity interventions using mass media, print media, and information technology. *American Journal of Preventive Medicine.* 1998, *15:*362–378.

(10) Conn V, Rantz M, Maas M, Wipke-Tevis D: Designing effective nursing interventions. *Research in Nursing & Health.* 2001, *24:*433–442.

(11) *Bocksnick J: Effectiveness of a Physical Activity Adherence Counseling Program With Older Females. Doctoral dissertation, University of Alberta: 1991.

(12) Floyd J, Medler S, Ager J, Janisse J: Age-related changes in initiation and maintenance of sleep: A meta-analysis. *Research in Nursing & Health.* 2000, *29:*106–117.

(13) Cook DJ, Guyatt GH, Ryan G, et al.: Should unpublished data be included in meta-analyses? *Journal of the American Medical Association*. 1993, *269:*749–753.

(14) Kinney MR, Burfitt SN, Stullenbarger E, Rees B, DeBolt MR: Quality of life in cardiac patient research: A meta-analysis. *Nursing Research.* 1996, *45:*173–180.

(15) *Elder JP, Williams SJ, Drew JA, Wright BL, Boulan TE: Longitudinal effects of preventive services on health behaviors among an elderly cohort. *American Journal of Preventive Medicine.* 1995, *11:*354–359.

(16) Jette A, Rooks D, Lachman M, et al.: Home-based resistance training: Predictors of participation and adherence. *Gerontologist*. 1998, *38:*412–421.

(17) Clark B, Wade M, Massey B, Van Dyke R: Response of institutionalized geriatric mental patients to a twelve-week program of regular physical activity. *Journals of Gerontology* Series *A Biological Science & Medical Sciences*. 1975, *30:*565–573.

(18) Cunningham DA, Rechnitzer PA, Howard JH, Donner AP: Exercise training of men at retirement: A clinical trial. *Journals of Gerontology Series A Biological Science & Medical Sciences.* 1987, *42:*17–23.

(19) Ettinger WH, Burns R, Messier SP: A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis: The Fit-

ness Arthritis and Seniors Trial (FAST). *Journal of the American Medical Association.* 1997, *277:*25–31.

(20) MacRae PG, Asplund LA, Schnell JF, Ouslander JG, Abrahamse A: Walking program for nursing home residents: Effects on walk endurance, physical activity, mobility, and quality of life. *Journal of the American Geriatrics Society.* 1996, *44:*175–180.

(21) Nony P, Cucherat M, Haugh M, Boissell J: Critical reading of the meta-analysis of clinical trials. *Therapie.* 1995, *50:*339–351.

(22) King AC, Rejeski WJ, Buchner D: Physical activity interventions targeting older adults: A critical review and recommendations. *American Journal of Preventive Medicine.* 1998, *15:*316–333.

(23) Simmons-Morton DG, Calfas KJ, Oldenburg B, Burton NW: Effects of interventions in health care settings on physical activity and cardiorespiratory fitness. *American Journal of Preventive Medicine.* 1998, *15:*413–430.

(24) Cohen J: *Statistical Power Analysis for the Behavioral Sciences* (2nd Ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc., 1988.

(25) Cooper HM, Hedges LV (eds): *The Handbook of Research Synthesis.* New York: Russell Sage Foundation, 1994.

(26) Raudenbush SW: Random effects models. In Cooper HM, Hedges LV (eds), *The Handbook of Research Synthesis*. New York: Russell Sage Foundation, 1994, 301–321.

(27) Lipsey M, Wilson D: *Practical Meta-Analysis*. Thousand Oaks, CA: Sage, 2001.

(28) *Agurs TD: Efficacy of a Weight Loss and Exercise Intervention for Older African Americans With Non-Insulin-Dependent Diabetes Mellitus. Doctoral dissertation, The Pennsylvania State University: 1995.

(29) *Atkins C, Kaplan R, Timms R, Reinsch S, Lofback K: Behavioral exercise programs in the management of chronic obstructive pulmonary disease. *Journal of Consulting & Clinical Psychology.* 1984, *52:*591–602.

(30) *Booth M, Bauman A, Oldenburg B, Owen N, Magnus P: Effects of a national mass media campaign on physical activity participation. *Health Promotion International.* 1992, *7:*241–247.

(31) *Burdsall G: The Development, Implementation, and Evaluation of a Lifestyle Education and Exercise Program for Senior Adult Learners at Three Kansas Congregate Meal Sites. Doctoral dissertation, University of Kansas: 1994.

(32) *Burton LC, Paglia MU, German PS, Shapiro S, Damiano AM: The effect among older persons of a general preventive visit on three health behaviors: Smoking, excessive alcohol drinking, and sedentary lifestyle. *Preventive Medicine.* 1995, *24:*492–497.

(33) *Cupples ME, McKnight A: Randomised controlled trial of health promotion in general practice for patients at high cardiovascular risk. *British Medical Journal.* 1994, *309:*993–996.

(34) *Frandin K, Johannesson K, Grimby G: Physical activity as part of an intervention program for elderly persons in Goteborg. *Scandinavian Journal of Medicine & Science in Sports.* 1992, *2:*218–224.

(35) *French SL: The Self-Management of Osteoarthritis in Older Women: A Study of the Efficacy of the Arthritis Self-Management Program and of the Factors Influencing Outcomes. Doctoral dissertation, Queen's University at Kingston: 1995.

(36) *Friedman R: Automated telephone conversations to assess health behavior and deliver behavioral interventions. *Journal of Medical Systems.* 1998, *22:*95–102.

(37) *Fries J, Fires S, Parcell C, Harrington H: Health risk changes with a low-cost individualized health promotion program: Effects at up to 30 months. *American Journal of Health Promotion.* 1992, *6:*364–371.

(38) *Gillett P, Caserta M: Change in aerobic power, body-composition, and exercise adherence in obese, postmenopausal women 6 months after exercise training. *Menopause.* 1996, *3:*126–132.

(39) *Hamdorf PA, Withers RT, Penhall RK, Plummer JL: A follow-up study on the effects of training on the fitness and habitual activity patterns of 60- to 70-year-old women. *Archives of Physical Medicine and Rehabilitation.* 1993, *74:*473–477.

(40) *Lalonde B, Hooyman N, Blumhagen J: Long-term outcome effectiveness of a health promoting program for the elderly: The Wallingford Wellness Project. *Journal of Gerontological Social Work.* 1998, *13:*95–112.

(41) *Leaf DA, Reuben DB: "Lifestyle" interventions for promoting physical activity: A kilocalorie expenditure-based home feasibility study. *American Journal of Medical Science.* 1996, *312:*68–75.

(42) *Leveille SG, Wagner E, Davis C, et al.: Preventing disability and managing chronic illness in frail older adults: A randomized trial of a community-based partnership with primary care. *Journal of the American Geriatrics Society.* 1998, *46:*1314–1316.

(43) *Marcus BH, Goldstein MG, Jette A, et al.: Training physicians to conduct physical activity counseling. *Preventive Medicine.* 1997, *26:*382–388.

(44) *Matteson MA: Effects of a cognitive behavioral approach and positive reinforcement on exercise for older adults. *Educational Gerontology.* 1989, *5:*497–513.

(45) *Minor MA, Hewett JE, Webel RR, Anderson SK, Kay DR: Efficacy of physical conditioning exercise in patients with rheumatoid arthritis and osteoarthritis. *Arthritis & Rheumatism.* 1989, *32:*1396–1405.

(46) *Modra AK, Black DR: Peer-led minimal intervention: An exercise approach for elderly women. *American Journal of Health Behavior.* 1999, *23:*52–60.

(47) *Montgomery EB, Lieberman A, Singh G, Fries JF: Patient education and health promotion can be effective in Parkinson's disease: A randomized controlled trial. PROPATH Advisory Board. *American Journal of Medicine.* 1994, *97:*429–435.

(48) *Morey MC, Cowper PA, Feussner JR, et al.: Two-year trends in physical performance following supervised exercise among community-dwelling older veterans. *Journal of the American Geriatrics Society.* 1991;39:986–992.

(49) *Nelson E, McHugo G, Schnurr P, et al.: Medical self-care education for elders: A controlled trial to evaluate impact. *American Journal of Public Health.* 1984, *74:*1357–1362.

(50) *Osler M, Jespersen NB: The effect of a community-based cardiovascular disease prevention project in a Danish municipality. *Danish Medical Bulletin.* 1993, *40:*485–489.

(51) *Owen N, Bauman A, Booth M, Oldenburg B, Magnus P: Serial mass-media campaigns to promote physical activity: Reinforcing or redundant? *American Journal of Public Health.* 1995, *85:*244–248.

(52) *Prosser G, Carson P, Phillips R: Exercise after myocardial infarction: Long-term rehabilitation effects. *Journal of Psychosomatic Research.* 1985, *29:*535–540.

(53) *Rainey J: Attributions to Exercise and Adherence to an Exercise Program. Doctoral dissertation, University of South Carolina: 1992.

(54) *Rejeski WJ, Brawley LR: Shaping active lifestyles in older adults: A group-facilitated behavior change intervention. *Annals of Behavioral Medicine.* 1997, *19*(Suppl.):S106.

(55) *Rejeski WJ, Brawley LR, Ettinger W, Morgan T, Thompson C: Compliance to exercise therapy in older participants with knee osteoarthritis: Implications for treating disability. *Medicine & Science in Sports & Exercise.* 1997, *29:*977–985.

(56) *Rowland L, Dickinson EJ, Newman P, Ford D, Ebrahim S: Look After Your Heart programme: Impact on health status, exercise knowledge, attitudes, and behaviour of retired women in England. *Journal of Epidemiology & Community Health.* 1994, *48:*123–128.

(57) *Scales R: Motivational Interviewing and Skill-Based Counseling in Cardiac Rehabilitation. Doctoral dissertation, University of New Mexico: 1997.

(58) *Stevens W, Hillsdon M, Thorogood M, McArdle D: Cost-effectiveness of a primary care based physical activity intervention in 45–74 year old men and women: A randomised controlled trial. *British Journal of Sports Medicine.* 1998, *32:*236–241.

(59) *Stewart AL, Mills KM, Sepsis PG, et al.: Evaluation of CHAMPS, a physical activity promotion program for older adults. *Annals of Behavioral Medicine.* 1998, *19:*353–361.

(60) *Trowbridge B: The Effect of a Selected Exercise Program on the Attitudes of Elderly Men Toward Exercise and Physical Activity. Doctoral dissertation, University of Oregon: 1978.

(61) *Trujillo KA: Developmental Approach to Exercise Intervention. Doctoral dissertation, University of Southern California: 1994.

(62) *Wiggam J, French R, Henderson H: The effects of a token economy on distance walked by senior citizens in a retirement center. *American Corrective Therapy Journal.* 1986, *40:*6–12.

(63) *Wisnewski CA: A Study of the Health-Promoting Behavioral Effects of an Exercise Educational Intervention in Adult Diabetics. Doctoral dissertation, Texas Women's University: 1996.

(64) *Wood ER: Evaluation of a hospital-based education program for patients with diabetes. *Journal of the American Dietetic Association.* 1989, *89:*354–358.

(65) *Yaffe D: Increasing Physical Exercise Among Older Adults: The Effects of Information, Peer-Modeling, Personalized Planning, and Commitment-Making. Doctoral dissertation, Virginia Polytechnic Institute and State University: 1996.

(66) Cooper HM: *Integrating Research: A Guide for Literature Reviews* (2nd Ed.). Newbury Park, CA: Sage, 1989.

(67) Blair SN, Applegate WB, Dunn AL, et al.: Activity Counseling Trial (ACT): Rationale, design, and methods. *Medicine & Science in Sports & Exercise.* 1998, *30:*1097–1106.

(68) Topp R, Mikesky A, Wigglesworth JK, Holt W, Edwards JE: The effect of a 12-week dynamic resistance strength training program on gait velocity and balance of older adults. *Gerontologist.* 1993, *33:*501–506.

(69) Topp R, Mikesky A, Thompson K: Determinants of four functional tasks among older adults: An exploratory regression analysis. *Journal of Orthopaedic & Sports Physical Therapy.* 1998, *27:*144–153.