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Obese, Older Adults With Knee Osteoarthritis: Weight Loss, Exercise, and Quality of Life

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This study examined the effects of dietary weight loss and exercise on the health-related quality of life (HRQL) of overweight and obese, older adults with knee osteoarthritis. A total of 316 older men and women with documented evidence of knee osteoarthritis were randomly assigned to 1 of 4 18-month interventions: dietary weight loss, exercise, dietary weight loss and exercise, or healthy lifestyle control. Measures included the SF-36 Health Survey and satisfaction with body function and appearance. Results revealed that the combined diet and exercise intervention had the most consistent, positive effect on HRQL compared with the control group; however, findings were restricted to measures of physical health or psychological outcomes that are related to the physical self.

Key words: health-related quality of life, weight loss, exercise, aging, knee osteoarthritis

Osteoarthritis (OA) of the knee is a chronic disease that is strongly related to obesity (Anderson & Felson, 1988), most common among older women (Lawrence et al., 1998), and a major cause of physical disability with aging (Verbrugge, 1990). The major symptoms of knee OA are joint pain and stiffness (Davis, 1988; Felson et al., 1987). Because there is no known cure for this disease, much of the focus in medicine is on palliative care; that is, the treatment objective is to improve or to maintain health-related quality of life (HRQL). In recent years, there has been increasing evidence that physical activity is an effective treatment to reduce pain and to increase the physical function of older persons with knee OA (Ettinger et al., 1997; Kovar et al., 1992; Minor, Hewett, Webel, Anderson, & Kay, 1989). The arthritis, diet, and activity promotion trial (ADAPT) is an extension of this research effort that has examined the combined impact of weight loss and physical activity on the functioning of overweight and obese, older adults who have knee OA. The current investigation describes the impact of the interventions in ADAPT on HRQL.

A study by Felson and his colleagues (Felson, Zhang, Anthony, Naimark, & Anderson, 1992) on the Framingham cohort revealed that a weight loss of approximately 5.1 kg over a 10-year period decreased the odds of developing knee OA by more than 50%. Obesity is also known to exacerbate pain and disability once the disease is clinically manifest (Hartz, Fischer, Bril, & Kelber, 1986). In fact, it is well recognized that obesity compromises health status independent of any effects compounded by knee OA. For example, Kushner and Foster (2000) noted that dissatisfaction with quality of life is one of the major reasons that individuals seek medical attention for obesity. Fontaine, Cheskin, and Barofsky (1996) reported that most subscales of the SF-36 Health Survey (SF-36), a generic measure of HRQL, were more negatively affected by body mass index (BMI) as level of obesity became more severe. There are some data to suggest that the psychological consequences of obesity are more serious in women than in men (Sullivan et al., 1993). Moreover, the effects of obesity on psychological outcomes appear to be stronger for measures that tap perceptions related to physical as opposed to emotional health (Fontaine & Barofsky, 2001; Kushner & Foster, 2000). As concluded in a recent review by Kushner and Foster (2000), there have been very few data from randomized controlled trials concerning the effects of weight loss on quality of life outcomes.

A number of different investigators have found various forms of physical rehabilitation to be effective in improving symptoms that accompany knee OA. Specific benefits of interest in this population include a reduction in knee pain (Ettinger et al., 1997; Fisher & Pendergast, 1994) and an enhancement of both objective (Ettinger et al., 1997; Minor et al., 1989) and subjective (Ettinger et al., 1997; Messier et al., 2000) measures of physical function. Minor and her colleagues (Minor et al., 1989) noted that a 12-week exercise program of either aquatics or walking improved depressive affect and anxiety among middle-aged adults who had either rheumatoid arthritis or osteoarthritis. In our research with knee OA, we have found that exercise therapy leads to an improvement in control beliefs related to the performance of functional tasks (Rejeski, Ettinger, Martin, & Morgan, 1998). Moreover, these beliefs were found to mediate the favorable change that was found on performance-based functional tasks following 18 months of exercise intervention (Rejeski, Martin et al., 1998).

Finally, we now have data to suggest that exercise combined with dietary weight loss is an effective weight-loss intervention for

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obese, osteoarthritic older adults (Messier et al., 2000). More specifically, a group of obese older adults with knee osteoarthritis lost 8.5 kg across a 6-month intervention using a diet-plus-exercise intervention compared with a 1.8 kg weight loss for a similar group using an exercise-only intervention. Recently, Huang and colleagues (Huang et al., 2000) compared a triple-therapy weight-reduction program that combined acupuncture, diet, and exercise with a similar intervention that included pain therapy and an intervention of pain therapy only. The authors found that the interventions that included acupuncture, diet, and exercise improved weight loss, disability, and walking speed compared with pain therapy alone.

The current article focuses on how dietary weight loss and exercise influence the composite mental and physical health scores of the SF-36 as well as measures of satisfaction with physical function and satisfaction with appearance. The SF-36 is a generic measure of HRQL, whereas the satisfaction measures were included to tap more specific end points that relate conceptually to the intervention and population under investigation. Secondary analyses were conducted on the eight subscales of the SF-36.

Participants in this study were randomized to one of four treatments: exercise only, dietary weight loss only, dietary weight loss plus exercise, or a healthy lifestyle control condition. In a previous 6-month pilot study (Messier et al., 2000), the authors found that older, obese adults with knee OA experienced improvements in both self-reported disability and performance-based measures of functional limitations. However, the diet and exercise group experienced greater improvement in a biomechanical assessment of kinetics (i.e., the rate at which weight is loaded during walking for the leg with the greatest knee pain) and walking stride length. On the basis of these data and research showing that obesity has a detrimental effect on HRQL (cf. Fontaine & Barofsky, 2001), we hypothesized that, in comparison to the control group, the combined dietary weight-loss and exercise treatment would have the most consistent positive effect on the primary outcomes of interest in this study. Consistent with previous reviews (Fontaine & Barofsky, 2001; Kushner & Foster, 2000), we anticipated that the effects would be more likely to occur for outcomes that tapped physical health as opposed to mental health.

Method

Design

ADAPT was a single-blind, randomized controlled trial with 18 months of follow-up. Participants were assigned to one of four treatments: exercise only, dietary weight loss only, dietary weight loss plus exercise, or a healthy lifestyle control condition. The study was conducted at the Claude D. Pepper Older Americans Independence Center of Wake Forest University with the approval of the institutional review board.

Participants

The eligibility criteria for participation in the study were (a) age ≥ 60 years; (b) calculated BMI ≥ 28; (c) knee pain on most days of the month; (d) sedentary activity pattern with less than 20 min of formal exercise once per week for the past 6 months; (e) self-reported difficulty in at least one of the following activities ascribed to knee pain: walking .25 mile (3–4 city blocks), climbing stairs, bending, stooping, kneeling (e.g., to pick up clothes), shopping, housecleaning; or other self-care activities, such as getting in and out of bed, standing up from a chair, lifting and carrying groceries, or getting in and out of the bathtub; (f) radiographic evidence of tibio-femoral osteoarthritis as determined by a single observer and on the basis of weight-bearing anteroposterior x-rays (Altman et al. 1986); and (g) willingness to undergo testing and intervention procedures.

Exclusion criteria included having the following: (a) a serious medical condition that prevented safe participation in an exercise program, such as coronary artery disease, severe hypertension, peripheral vascular disease, stroke, congestive heart failure, chronic obstructive pulmonary disease, insulin-dependent diabetes, psychiatric disease, renal disease, liver disease, active cancer other than skin cancer, and anemia; (b) a Mini-Mental score < 24; (c) an inability to complete the 18-month study or unlikely to be compliant; (d) an inability to walk without a cane or other assistive device; (e) participation in another research study; (f) excessive alcohol use with a cutoff of ≥ 14 drinks per week; or (g) an inability to complete the protocol, in the opinion of the clinical staff, because of frailty, illness, or other reasons.

As a result of mass mailings to age-eligible persons within the target area and other more focused recruitment strategies (e.g., letters to minority churches), a total of 2,209 older adults were prescreened through telephone interviews. Of this population, 1,596 did not meet one or more of the inclusion/exclusion criteria and another 297 refused to be contacted any further. A total of 316 individuals were eventually randomized into the study. The group assignments were as follows: 78 in the healthy lifestyle education control group, 82 in diet only, 80 in exercise only, and 76 in the combined diet/exercise intervention.

Measures

SF-36. The SF-36 (Ware, Kosinski, & Keller, 1997) is a generic measure of health status/HRQL that consists of two norm-based composite *T* scales, Mental Health and Physical Function, and eight subscales: Physical Functioning, Mental Health, Role–Physical, Role–Emotional, Bodily Pain, General Health, Vitality, and Social Functioning. The norm-based composite scales both have a mean of 50 and a standard deviation of 10, whereas the subscales are typically reported as scores that range from 0–100. Higher scores on all SF-36 scores indicate more favorable levels of function. There has been extensive data published in support of the psychometric properties of this instrument (Ware, Keller, Hatoum, & Kong, 1999). This measure has been used in the study of obese persons (Fontaine et al., 1996) and in clinical trials involving knee replacement surgery associated with osteoarthritis (Bombardier et al., 1995; Hawker, Melfi, Paul, Green, & Bombardier, 1995).

Satisfaction with physical function and appearance. The body satisfaction measure consists of six items that tap physical function (e.g., your physical ability to do what you want or need to do) and three items that tap body appearance (e.g., your shape). Each item is rated on a 7-point scale that is scored from -3 to $+3$ with numbers on the scale anchored by the following phrases: *very dissatisfied* (-3), *somewhat dissatisfied* (-2), *a little dissatisfied* (-1), *neither* (0), *a little satisfied* ($+1$), *somewhat satisfied* ($+2$), *very satisfied* ($+3$). A recent publication using both exploratory and confirmatory factor analyses has shown that the nine items load on the two aforementioned factors, each having a Cronbach's alpha internal consistency reliability above .90 (Reboussin et al., 2000). The subscales also have good convergent validity and other favorable psychometric properties. Rejeski and his colleagues (Rejeski et al., 2001) have shown that both subscales demonstrate sensitivity to change with an exercise intervention.

BMI. BMI was calculated as weight in kilograms divided by height in square meters. Assessment of height and weight was obtained by standardized procedures at scheduled follow-up clinic visits.

Demographics and comorbidities. Age, race, education, income, and data on comorbidities were acquired by self-report. Income and education were both grouped into the categories that appear in Table 1. For comorbidities, participants were asked to check yes or no boxes for various chronic conditions. Assistance was offered to participants who were unclear about the nature of a particular disease or condition. The cardiovascular disease category included participants who reported one or more of

Table 1
Selected Demographic Characteristics (Means, Standard Deviations, or Percentages) for the Arthritis, Diet, and Activity Promotion Trial Participants

		Grouping			
Variable	Overall	Control (n = 68)	Diet (n = 73)	Exercise (n = 69)	Diet + Exercise (n = 68)
Age (years)					
M	68.52	68.59	68.09	68.96	68.46
SD	6.30	6.29	5.53	6.62	5.62
Weight (kg)					
M	93.75	95.80	95.06	92.14	91.93
SD	16.54	18.85	15.18	14.62	17.27
BMI					
M	34.54	34.76	34.67	34.55	34.17
SD	5.62	5.33	5.14	5.80	5.63
Gender					
Male	28.03	33.33	25.93	26.25	26.67
Female	71.97	66.67	74.07	73.75	73.33
Obese (BMI > 30)					
Yes	78.64	77.63	81.25	84.81	70.27
No	21.36	22.37	18.75	15.19	29.73
High blood pressure					
Yes	48.73	44.87	51.22	55.00	43.42
No	51.27	55.13	48.78	45.00	56.58
Cardiovascular disease					
Yes	15.51	15.38	13.41	16.25	17.11
No	84.49	84.62	86.59	83.75	82.89
Diabetes					
Yes	9.49	8.97	6.10	11.25	11.84
No	90.51	91.03	93.90	88.75	88.16
Race					
Caucasian	75.99	79.73	70.89	76.62	77.03
Other	24.01	20.27	29.11	23.38	22.97
Income					
< $15,000	18.42	18.92	18.99	16.88	18.92
$15,000–$35,000	32.89	29.73	32.91	32.47	26.49
$35,000–$50,000	22.37	16.18	24.05	29.87	20.27
> $50,000	26.32	36.49	24.04	20.78	24.32
Education					
< HS	1.97	4.05	2.53	1.30	0.00
HS education	9.54	10.81	7.59	9.09	10.87
At least 1 year after HS	85.14	89.87	89.19	89.61	89.19

Note. There were no statistically significant differences ($p > .05$) between the treatment groups on any of the demographic variables listed. BMI = body mass index; HS = high school.

the following: angina, congestive heart failure, or a myocardial infarction (heart attack).

Procedures

Following the recruitment process, potential participants attended a series of clinic visits for final screening to verify that they met the aforementioned inclusion and exclusion criteria. Baseline assessments were completed during this interval of time, informed consents were obtained, and eligible participants were randomized to one of four treatment groups. As mentioned previously, these treatments included exercise only, diet only, diet and exercise, and a healthy lifestyle control comparison group. The treatments lasted 18 months, with data collection repeated at 6 and 18 months postrandomization. Only staff members who were masked to treatment assignment were involved in data collection.

Interventions

Exercise. The 3-day-per-week exercise program, prescribed to each participant randomized to either the exercise or diet and exercise groups, consisted of an aerobic phase (15 min), a resistance-training phase (15 min), a second aerobic phase (15 min), and a cool-down phase (15 min). The first 4 months of the 18-month intervention were facility based. At any time after the first 4 months, participants who wished to exercise at home underwent a 2-month transition phase, in which the participant alternated between the facility and the home. Hence, some participants remained in a facility-based program, others opted for a home-based program, and some participants chose a combined facility/home-based program. At the beginning of a home-based phase, exercise leaders made home visits to work with the participants in tailoring individualized exercise regimens that were consistent with the study protocol.

The aerobic exercise prescription included walking within a heart rate range of 50%–75% of heart-rate reserve, whereas the resistance-training portion of the program consisted of two sets of 12 repetitions of the following exercises: (a) leg extension, (b) leg curl, (c) heel raise, and (d) step up. Cuff weights and weighted vests were used to provide resistance, and a 1–1.5-min rest interval separated each exercise. Following two orientation sessions, participants began with the lowest possible resistance. Weight was increased after the participant performed two sets of 12 repetitions for 2 consecutive days. For participants in the home-based program, weights were exchanged at the participant's request or after a determination was made to increase weight during face-to-face or telephone contact. Telephone contacts were made biweekly during the first 2 months of home-based exercise, every 3 weeks during the following 2 months, and monthly thereafter. Additional home visits or facility-based booster sessions were scheduled to assist participants who were having difficulty complying with the home-based exercise intervention. The lead interventionists for this phase of the trial had degrees in exercise science, with experience in exercise programming for special populations. Exercise and attendance logs were used to gather data and to monitor progress. *Exercise compliance* was defined as the number of exercise sessions completed divided by the total number of prescribed sessions.

Dietary weight loss. The goal of the dietary weight-loss intervention was to produce and maintain an average weight loss of 5% across the 18-month intervention period. The weight-loss goal was based on the results of the Trial of Nonpharmacologic Interventions in the Elderly (TONE), in which obese, hypertensive, older adults were able to maintain a 5.4% decrease in body weight over 2.5 years (Appel et al., 2001). Participants who were assigned to the combined exercise and dietary treatment condition attended separate sessions for the modification of their physical activity and dietary behaviors.

The dietary intervention was based on principles from the group dynamics literature (Cartwright & Zander, 1953) and social–cognitive theory (Bandura, 1986) and was divided into three phases, intensive (Months 1–4), transition (Months 5–6), and maintenance (Months 7–18). The major emphasis of the intensive phase was to heighten awareness of the importance of and the need to change eating habits to lower caloric intake. Behavior change was facilitated through the use of self-regulatory skills. These skills included self-monitoring, goal setting, cognitive restructuring, problem solving, and environmental management. One introductory individual session was followed by 16 weekly sessions consisting of 3 group sessions and 1 individual session each month. Each group session included problem solving, reviewing a specific topic, and food tasting of several well-balanced, low-fat, nutritious meals prepared with widely available food products. The individual sessions were used to review individual progress, solve problems, answer questions, and set goals. Body weight was measured weekly in both the diet-only and diet and exercise treatment conditions and was recorded to the nearest 0.05 kg. The transition phase included 8 weeks of biweekly contacts (three group sessions and one individual session). The goals for this phase included (a) assisting participants who had not reached their weight goals to reestablish new goals and (b) maintaining and preventing relapse in those participants who had reached their weight-loss goals. The maintenance phase included monthly meetings and phone contacts alternated every 2 weeks. Additionally, newsletters were mailed at regular intervals that provided pertinent nutritional information and notice of upcoming meetings. The goals of the maintenance phase included (a) assisting participants who had reached their weight loss goals to maintain this weight loss and (b) providing counsel for participants who had had a difficult time losing weight and adhering to the intervention. The interventionists who led the dietary weight-loss therapy were registered dieticians who had been specifically trained to deliver the ADAPT weight loss program. Adherence to the intervention was based on attendance to scheduled sessions and completion of the monthly weight assessment.

Healthy lifestyle control. The healthy lifestyle control group served as a comparison group to the three intervention groups and was designed to provide attention, social interaction, and health education. The group met monthly for 1 hr for the first 3 months. A health educator, who scheduled videotaped presentations and physician talks on topics concerning osteoarthritis, obesity, and exercise, organized the healthy lifestyle program. Question and answer sessions followed each presentation. Monthly phone contact was maintained during Months 4–6 and bi–monthly contact during Months 7–18. During phone contact, information on pain, medications, illnesses, and hospitalization was obtained. Participants were also given an opportunity to ask questions about their disease and to voice any concerns they had regarding their health. *Compliance* was defined as the number of sessions attended divided by the total number of sessions offered. This result was then multiplied by a factor of 100 to create percent compliance.

Statistical Analyses

Potential differences in baseline characteristics between participants randomized to the four treatment groups were examined by analysis of variance and chi-square tests. The effects that the diet and/or exercise interventions had on the SF-36 and measures of satisfaction were examined using 4 (treatment groups) × 2 (time) repeated measures analysis of covariance (ANCOVA). Analyses for group differences were adjusted for the prerandomized levels of the baseline value of the outcome being analyzed, age and gender. Analyses were conducted using SAS PROC MIXED, a procedure that used all of the available follow-up information collected at the 6- and 18-month assessments. This procedure provides maximum-likelihood estimates allowing for missing data. The method enables missing data to be dependent on baseline and other observed data and provides unbiased estimates making a missing at random assumption. When Group × Time interactions were nonsignificant, average intervention effects over the follow-up period were estimated and tested for significance. Primary analyses were conducted by intent to treat, with participants analyzed according to the initial randomized assignments. All tests of hypotheses and reported p values were two sided.

Results

As shown in Table 1, most of the participants in this trial were obese (78.64%), older women (71.97%) who were Caucasian. The most prevalent comorbidity was hypertension (48.73%), with 15.51% having cardiovascular disease and 9.49% having diabetes. The mean (standard deviation) composite mental health T score from the SF-36 at baseline was 53.23 (9.78), whereas the composite score for physical health was 34.65 (9.24). These latter data illustrate that knee osteoarthritis in this community sample of older adults had no adverse effect on mental health, yet was associated with a physical health score that was 1.5 standard deviation units below the population mean.

Checks on Efficacy of Interventions

Of the 316 participants who were originally randomized into treatment, 80% completed the study and there was no difference in the number of dropouts between treatments; that is, the retention rate was 78% in the control group, 80% in the diet-only group, 82% in the exercise group, and 76% in the diet and exercise group. Moreover, adherence to the prescribed treatment regimen was excellent across the 18 months of the study. The healthy lifestyle control group had a 75% rate of adherence to scheduled contacts, whereas participants in the dietary weight-loss-only group attended 72% of the nutrition classes and those in the exercise-only group completed 60% of the assigned exercise sessions. When you average the diet and exercise sessions completed for those in the combined treatment, the rate of adherence was 64%. Over the course of the 18 months of the study, the control group lost 1.3% of body weight and there was a 2.6% weight loss among those in the exercise-only treatment condition. Those in the diet-only treatment group lost 5.7% of body weight, whereas those in the diet and exercise group lost 4.4%. There was a statistically significant group effect for weight loss, $F(3, 261) = 9.66$, $p < .01$, with participants in the diet-only and combined treatment conditions losing more weight than those in the control or exercise-only treatment conditions. It was also interesting to note that those participants in the exercise-only and combined treatment conditions experienced significant gains in a 6-min walk test relative to the control group, $F(3, 238) = 13.02$, $p < .01$ (Messier et al., 2002). The exercise-only group had a mean improvement in the 6-min walk distance of 9.3% and the diet and exercise group a mean improvement of 12.2%, whereas the diet-only and control groups improved 2.8% and −0.8%, respectively.

Group Comparisons for the Primary Objectives of This Study

The primary objectives of this study were to conduct treatment comparisons on the SF-36 composite scores for mental and physical health as well as treatment comparisons for satisfaction with physical function and satisfaction with appearance. Whereas the two-way ANCOVA conducted on the composite mental health score of the SF-36 failed to produce any significant effects, there was a significant group effect for the composite physical health score of the SF-36, $F(3, 265) = 5.74$, $p = .0008$. Examination of the adjusted postrandomization group means in Table 2 for the composite physical health scale illustrates that the combined diet and exercise treatment was the only condition that experienced statistically significant improvement on this measure compared with the control group, effect size (ES) = 0.73. Although not statistically different from either the control or combined treatment group, the diet-only and exercise-only treatment means were in the predicted direction from the control condition, ESs = 0.41 and 0.33, respectively.

Analyses of the satisfaction with function and satisfaction with appearance scales produced significant group effects for both measures, $F(3, 265) = 7.65$, $p < .01$ and $F(3, 265) = 8.26$, $p < .01$, respectively. As shown in Table 2, both the exercise-only and combined diet and exercise intervention groups had higher satisfaction with their physical function than did the control group, ESs = 0.49 and 0.85, respectively. The diet-only group did not differ from the control or exercise-only group, yet had lower satisfaction ratings for physical function than the combined group. Interestingly, for satisfaction with appearance, the diet-only, exercise-only, and combined treatment group means were all statistically different from the control group, ESs = 0.66, 0.46,

Table 2
Mean and Standard Error Scores for Composite SF-36 Health Survey Scales and Satisfaction Measures by Group

	Group assignment							
	Control		Diet		Exercise		Diet + Exercise	
Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Composite mental health								
Baseline	52.70	1.33	52.69	1.04	54.28	1.00	52.85	1.31
Follow-up	53.51	1.20	53.89	0.97	52.85	1.26	53.31	0.99
Adjusted follow-up	53.70	0.80_a	54.39	0.78_a	54.06	0.81_a	53.84	0.82_a
Composite physical health								
Baseline	33.60	1.03	35.17	1.05	34.50	1.14	35.39	1.28
Follow-up	34.41	1.09	38.20	1.13	37.14	1.25	40.57	1.33
Adjusted follow-up	35.33	0.84_a	38.15	$0.81_{a,b}$	37.61	$0.85_{a,b}$	40.31	0.86_b
Satisfaction with function								
Baseline	−1.56	0.16	−0.99	0.19	−1.09	0.18	−1.04	0.17
Follow-up	−1.01	0.19	−0.24	0.18	−0.13	0.20	0.39	0.22
Adjusted follow-up	−0.74	0.16_a	−0.30	$0.16_{a,b}$	−0.09	$0.16_{b,c}$	0.38	0.17_c
Satisfaction with appearance								
Baseline	−1.92	0.15	−1.94	0.15	−1.31	0.13	−1.78	0.19
Follow-up	−1.61	0.15	−0.81	0.18	−0.93	0.19	−0.44	0.21
Adjusted follow-up	−1.56	0.16_a	−0.70	0.15_b	−0.96	0.16_b	−0.46	0.16_b

Note. Follow-up scores are an average of the 6- and 18-month data. Means in each row of the adjusted follow-up scores that share a common subscript do not differ at the $p < .01$ level, a corrected alpha level that was used to compensate for multiple pairwise comparisons. Covariates include the prerandomization levels of the outcome being analyzed, age, and gender.

and 0.85, respectively. However, there were no differences between the three active treatments on this measure. Although the dietary weight-loss-only and exercise-only interventions did not differ from one another on either satisfaction outcome, it is interesting to note that the mean for the dietary weight-loss-only condition was slightly more favorable for satisfaction with appearance, whereas the opposite was true for satisfaction with physical function.

Subscales Associated With the SF-36

As secondary analyses, group comparisons were conducted for each subscale of the SF-36. These comparisons yielded significant group effects for five of the eight subscales: physical functioning, $F(3, 265) = 5.05$, $p = .002$; general health, $F(3, 265) = 2.76$, $p = .042$; role–physical, $F(3, 265) = 2.70$, $p = .046$; body pain, $F(3, 265) = 4.33$, $p = .005$; and social functioning, $F(3, 265) = 4.41$, $p = .004$. Table 3 provides the intervention means and standard errors for each subscale of the SF-36. Post hoc comparisons illustrate that for the general health and the role–physical subscales, the only statistically significant pairwise comparison was between the control group and the combined diet and exercise group; albeit mean differences between the diet-only and exercise-only groups and the control group were in the predicted direction. As expected, the combined treatment group had higher scores on both subscales than the control group. For the physical functioning subscale, both the diet-only and combined treatment group had statistically higher scores than the control group, whereas the exercise-only group did not differ from any other treatment condition. Also, participants in the diet and exercise group had statistically lower body pain than those in the control group, whereas the diet-only and exercise-only groups did not report lower pain than those in the control group. It is also interesting to point out that all three group-based interventions had favorable and comparable effects on social functioning as compared with the control condition.

Tests of Moderation and Mediation for the Composite Physical Health Scale

Because the combined diet and exercise treatment condition was statistically different from the control condition on the composite physical health scale of the SF-36, we conducted further analyses to examine selective and conceptually relevant tests of moderation and mediation for this outcome. BMI and gender were considered as moderators, whereas measures of satisfaction with body function and body pain were considered as mediators. The moderator analyses involved the addition of Group × BMI and Group × Gender interaction terms into the original ANCOVA. Results of these analyses failed to support the position that either BMI or gender moderated the effect that the group treatments had on the composite physical health scale of the SF-36.

To examine whether satisfaction with function or body pain mediated the effects of the pairwise comparison between the control group and the combined diet and exercise group, we first established that change for both of these measures had significant bivariate relationships with change in the composite physical health scale, $r = .38$, $p < .01$ for satisfaction with physical function and $r = .65$, $p < .01$ for body pain. Results of analyses reported in Tables 2 and 3 already established that the group intervention effect was related to change in each of the proposed mediators. Subsequently, we entered the baseline and follow-up scores for our measures of both satisfaction with function and body pain into the original statistical model. This was done for each

Table 3
Mean and Standard Error Scores for SF-36 Health Survey Subscales by Group

Measure	Control		Diet		Exercise		Diet + Exercise	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Mental health								
Baseline	77.70	2.09	76.71	1.67	78.89	1.63	77.50	2.14
Follow-up	78.65	1.85	78.21	1.53	79.95	1.42	79.06	1.76
Adjusted follow-up	78.56	1.19_a	79.21	1.16_a	79.33	1.20_a	79.68	1.23_a
Physical functioning								
Baseline	47.98	2.79	48.54	2.36	50.63	2.41	50.48	3.13
Follow-up	47.89	2.49	56.38	2.48	54.78	2.81	58.98	3.03
Adjusted follow-up	49.56	1.83_a	57.32	1.77_b	54.70	$1.84_{a,b}$	59.03	1.88_b
General health								
Baseline	62.41	2.35	65.83	2.29	62.13	2.41	62.70	2.46
Follow-up	61.15	2.16	67.50	2.12	62.86	2.31	67.53	2.62
Adjusted follow-up	61.94	1.67_a	66.32	$1.63_{a,b}$	64.26	$1.69_{a,b}$	68.51	1.72_b
Role–physical								
Baseline	34.93	4.26	39.04	4.27	37.68	4.66	42.19	4.91
Follow-up	41.42	4.48	48.63	4.43	50.19	4.80	59.18	4.93
Adjusted follow-up	43.45	3.77_a	49.36	$3.67_{a,b}$	51.95	$3.81_{a,b}$	58.63	3.88_b
Body pain								
Baseline	45.49	2.21	49.38	2.22	51.30	2.35	50.25	2.41
Follow-up	50.09	2.41	56.71	2.47	55.03	2.33	62.41	2.50
Adjusted follow-up	52.62	1.96_a	57.19	$1.90_{a,b}$	54.36	1.97_a	62.11	2.01_b
Vitality								
Baseline	44.49	2.67	50.41	2.17	48.91	2.46	49.69	2.42
Follow-up	50.11	2.54	53.04	2.31	51.17	2.64	55.20	2.54
Adjusted follow-up	52.60	1.85_a	52.49	1.79_a	51.63	1.85_a	54.53	1.89_a
Social functioning								
Baseline	78.31	3.05	76.03	3.21	80.80	3.05	77.34	2.93
Follow-up	75.55	3.32	84.08	2.31	85.25	2.16	84.38	2.60
Adjusted follow-up	75.43	2.32_a	85.49	2.27_b	84.50	2.35_b	85.42	2.39_b
Role–emotional								
Baseline	64.22	4.95	66.21	4.43	73.43	4.04	67.71	4.98
Follow-up	70.09	4.16	73.74	3.70	74.01	3.60	72.14	3.77
Adjusted follow-up	71.54	3.32_a	74.34	3.24_a	73.38	3.36_a	73.88	3.41_a

Note. Follow-up scores are an average of the 6- and 18-month data. Means in each row of the adjusted follow-up scores that share a common subscript do not differ at the $p < .01$ level, a corrected alpha level that was used to compensate for multiple pairwise comparisons. Covariates include the prerandomization levels of the outcome being analyzed, age, and gender.

proposed mediator separately and then combined so that we could evaluate any independence between the two mediators.

When we entered satisfaction with function into the original statistical model for the composite physical health scale, the group effect became nonsignificant, $F(3, 264) = 0.83$, $p = .48$. The magnitude of the effect that satisfaction with function had as a mediator can be seen through changes in the least square mean difference between the combined exercise and diet treatment and the control groups. In the original analysis (see Table 2), the least square mean difference between these two treatments was 4.98, whereas it decreased to 1.00 when including the effect of the intervention on satisfaction with function into the analysis. Similarly, when we entered body pain into the original statistical model for the composite physical health scale, the group effect once again became nonsignificant, $F(3, 264) = 1.76$, $p = .15$; in this instance, the least square mean difference between the combined treatment and control group decreased from a value of 4.98 to 1.67. Finally, we entered both mediators into a combined model. Obviously, the group effect for the composite physical health scale was once again nonsignificant, $F(3, 264) = 0.05$, $p = .96$. In this model, both satisfaction with function (β weight [$\pm$SE] = 1.56, $p < .01$) and body pain (β weight [$\pm$SE] = 0.27, $p < .01$) were independent mediators of follow-up scores on the composite physical health index. In this analysis, the least square mean difference between the combined treatment and the control groups was reduced from 4.98 in the original analysis to 0.46.

Discussion

To our knowledge, this is the first investigation to examine the effects of exercise and dietary weight loss on changes in HRQL among overweight and obese older adults with knee osteoarthritis. An examination of the baseline global mental and physical health scores from the SF-36 revealed that the study sample had a self-reported physical health status score that was 1.5 standard deviations below the population mean, whereas their global mental health score was identical to the population mean. On a scale that ranged from −3 to +3, this older group of patients also reported dissatisfaction with both their physical function (−1.17) and body appearance (−1.84). The values for these latter outcomes are considerably lower than normative data reported by Reboussin et al. (2000) for community-based sedentary adults over the age of 65 years, ESs = 0.90 and 0.89, respectively. This result reinforces the value of including condition-specific outcome measures when assessing the effects of behavioral interventions on HRQL (Rejeski, Brawley, & Shumaker, 1996). In addition, the findings are consistent with published reviews in the obesity literature that suggest obesity has its greatest impact on outcomes that are conceptually linked to the physical self (Fontaine & Barofsky, 2001; Kushner & Foster, 2000).

In examining pairwise treatment versus control condition comparisons across the 18 months of the study, it was clear that the treatment involving a combination of diet and exercise had the largest effect sizes and most consistent positive effect on HRQL, a result that was not moderated by either BMI or gender. This finding builds on existing obesity research, showing that the combined effect of exercise and diet on weight loss is superior to either treatment alone (Perri, 1998; Wing, 1999). The positive effect that the diet and exercise treatment had on HRQL occurred for all primary outcomes with the exception of the composite mental health score of the SF-36. There was no difference between any of the active treatment conditions and the control group for the mental health scale, a result that may be due, in part, to the fact that baseline scores were not depressed as other outcomes. There is good evidence from the exercise trials that treatment effects for psychological outcomes are strongly influenced by baseline scores (Rejeski et al., 1996).

As expected, patterns from the eight subscales of the SF-36 were, in general, consistent with the results from the composite scores. The one exception that deserves mention is the social functioning subscale. For this outcome, all of the active treatments differed from the control group, and the postrandomization means for the three treatment groups were virtually identical. This is an interesting result and suggests that the group interactions that accompanied the three treatments were effective in enhancing perceptions of social functioning (cf. Rejeski & Shumaker, 1994).

The data concerning satisfaction with physical function and appearance underscore the view that perceptions of physical function and appearance are salient to sedentary older adults (Martin, Leary, & Rejeski, 2000; Reboussin et al., 2000) and that the significance of these relationships increases in the presence of chronic conditions such as obesity and knee osteoarthritis that exacerbate functional limitations (Rejeski, Martin, Miller, Ettinger, & Rapp, 1998). The treatment differences in the current study are also consistent with previous research, in which increases in physical activity among sedentary middle- and older-aged adults produced improvements in both satisfaction with physical function and appearance (Rejeski et al., 2001); however, in this previous work, the changes in satisfaction with physical function were more dramatic than for appearance. Obvious differences between the two studies are that the earlier published work did not focus on overweight and obese older adults, nor did it include a dietary weight loss intervention.

The fact that the exercise-alone condition differed from the control group only on the social functioning subscale of the SF-36 and on the satisfaction subscales would appear to run counter to the broad favorable effects that exercise has been shown to have on the heath status of older adults with chronic disease (Rejeski et al., 1996). Given the statistically significant effects observed on the SF-36 in the diet and exercise condition, it appears that in obese populations the effect of exercise on perceived health status is only fully realized when exercise is coupled with weight loss. This may well be true of exercise in other subgroups or for more conceptually distant outcomes. For example, in a recent clinical trial, we found that the effect of exercise therapy on disability was greatly enhanced when participants were reinforced for and taught how to recapture their independence (Rejeski et al., 2002). Also, the reader may question whether group differences in therapist contact, as opposed to the diet and exercise behavior, were responsible for the observed results. However, if therapist contact was so influential, then the exercise-only group should have done better than the diet-only group because they had almost 3 times as much contact. This was not the case. In addition, we believe the argument for therapist contact would be stronger if the outcomes of concern involved mental health or social function. Interestingly, there were no group differences between the three active interventions on mental health or social functioning.

Because pain has been found to mediate measures of physical function (Rejeski, Ettinger, et al., 1998) and satisfaction with function has been found to mediate subjective well-being within the context of a previous physical activity trial (Rejeski et al., 2001), both of these measures were considered as potential mediators between the intervention and observed changes in the composite physical health scale of the SF-36. The analyses in the current study offer strong support to the position that the effects of the intervention on satisfaction with function and body pain are independent mediators for the effect that the intervention had on differences between the combined treatment and the control group for the composite physical health scale. These results suggest that future studies may well want to consider coupling interventions that target these mediators along with dietary weight-loss and/or physical activity programs (cf. Rejeski & Mihalko, 2001).

In summary, the findings of the present study suggest that lifestyle modifications of dietary and physical activity behaviors are important interventions for enhancing the HRQL of overweight and obese, older adults who have knee osteoarthritis. Although the dietary weight-loss-only and exercise-only interventions were effective in improving selected outcomes, it is clearly apparent that the combined intervention had the most consistent, positive effect on the outcomes of interest. The reader should bear in mind that the results of this study were restricted to outcomes related to physical health and psychological outcomes that are linked to the physical self. Furthermore, most participants in ADAPT were Caucasian women, a feature of the study design that places limitations on population validity.

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