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ORIGINAL RESEARCH

Theory-based approach for maintaining resistance training in older adults with prediabetes: adherence, barriers, self-regulation strategies, treatment fidelity, costs

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Abstract

Effectively preventing and treating chronic diseases through health behavior changes often require intensive theory- and evidence-based intervention including long-term maintenance components. We assessed the efficacy of theory-based maintenance approaches varying by dose for persistently performing resistance training (RT) with the hypothesis that a higher-dose social cognitive theory (SCT) approach would produce greater RT adherence than lower-dose Standard. The Resist-Diabetes study first established 2×/week resistance training (RT) in a 3-month supervised intervention in older (50–69 years, *N*=170), overweight to obese (BMI 25–39.9 kg/m^2) previously inactive adults who fit prediabetes criteria (fasting glucose concentration=95–125 mg/dl; oral glucose tolerance test 2-h glucose concentration=140–199 mg/dl or both). After the supervised phase, participants (*N*=159) were then randomly assigned to one of two conditions for transition (3 weeks) and then RT alone in community settings for extended contact, maintenance (6 months), and then no contact (6 months). SCT featured continued tailored, interactive personal, and web-based check-ups focused on RT, self-regulation, and a barrier/strategies approach. Standard involved low-dose, generic personal, and web-based check-ups within the same theoretical approach. SCT and Standard both resulted in similar RT, 2×/week adherence during maintenance (74.4 %) and no-contact phases (53.1 %). Cost analysis indicated the Standard intervention for transition and maintenance was inexpensive ($160). Standard can be translated into practice with the potential for continuous contact and persistence in RT beyond the typical program maintenance phase.

Keywords

Behavioral maintenance, Resistance training, Diabetes, Social cognitive theory, Health behavior change, Treatment fidelity, Cost

Implications

Practice Implications: Theory and evidence-based, lower-cost maintenance approaches for behavior change should be used within a continual care model for treatment of chronic diseases.

Policy Implications: Health care policies for prevention and treatment of chronic disease through behavior changes need to support theory and evidence-based initial interventions and, critically, also theory and evidence-based, lower-cost maintenance approaches.

Research Implications: A research focus needs to be on lower-cost, theory-based approaches to maintaining health behavior changes for preventing and treating chronic diseases within a continual care model.

INTRODUCTION

Maintenance–Treating chronic health conditions through lifestyle changes often requires evidence-based, initially intensive interventions to establish new health behaviors through successive mastery experiences and self-regulation skills so that conditions are abetted or reversed and the behaviors are potentially sustainable [1]. Intensive, evidence-based interventions are costly but potentially can be justified by future disease management offsets, future earnings and tax revenues, and improved health-related quality of life [2]. However, a caveat about the balance between costs and offsets is that behavior changes must be largely maintained at least for a number of years [3], if not, for a lifetime [4].

Maintenance of health behavior changes has continued to be a central issue, and perhaps, an obstacle, for routine prescription and reimbursement for intensive treatments [5]. Primary approaches for maintenance have revolved around the continual care model, essentially adopted from medical treatments of chronic diseases [6]. Continual treatment has included simply extending treatment or fading treatment after a relatively short intensive treatment phase. For example, in the Look AHEAD trial [7], while the dose of contacts was decreased after 1 year, the treatment dose was relatively high throughout year 2 of the intervention. Changes in weight, waist circumference, physical

activity, and cardiorespiratory fitness from year 1 were maintained into year 2. However, the dose of contact was further reduced in year 3 and there clearly was an erosion of those changes [see Fig. 1, reference 7] though some continued benefits [8] from a relatively expensive type of intervention [9].

Most other interventions, such as for weight loss [10], often have a briefer period (3–6 months) of intensive treatment, prepare people for maintenance through such self-regulation skills as problem solving and then, in an orderly way, fade out over an extended period (6–18 months) direct personal contact and other means of contact. There is evidence that this approach is an essential part of reducing weight regain after an intensive weight management program [10]. There also is evidence that the approach may be improved by teaching maintenance skills at the beginning of an intensive part of the intervention [11] and resources saved through a stepped care approach that only provides additional contact and help when needed [12]. Clearly, other intervention modalities that may be cost-effective such as those using the Internet and mobile technology need to be further developed and evaluated for longer-term maintenance.

The Resist-Diabetes study–These issues of efficacy and resources formed the backdrop for the Resist-Diabetes trial [13]. The major aims of this trial involved assessing the efficacy of brief, lower volume, and frequency resistance training (RT) fitting the American College of Sports Medicine's (ACSM) guidelines [14] for improving glycemic control, strength, and body composition in older (50–69 years), overweight to obese (BMI 25–39.9 kg/m^2), previously inactive adults with prediabetes [15]. There is a growing evidence base showing the efficacy of RT for glycemic control [16], but with minimal exceptions [17], extended training for 6 to 9 months has been entirely supervised [18, 19]. These studies established the efficacy and potential for RT to improve glycemic control but with the cost of an extended, intensive treatment. For greater prescription and translation into practice of RT for metabolic disorders and other conditions, e.g., for people surviving cancers [20], theory-based approaches [21] need to be developed and assessed for maintaining RT in typical community facilities once a relatively brief initial, intensive treatment phase ends.

There are elements of RT, for example, compared to a simple walking program that suggests an initial, intensive phase of treatment is needed [22]. The current prevalence rate in older adults of consistent performance of RT using the criteria of training all seven major muscle groups twice per week appears to be as low as 6 % [23]. This prevalence rate suggests minimal to no experience with RT for most people, and thus, skill training for RT is critical. For example, new evidence dispels the more than century-old weight lifting model that revolves around lifting heavier weights, sometimes with rapid or even explosive repetitions, with the assumption that external force is the major stimulus from RT [22]. Alternatively, new evidence shows that the major stimulus from RT for increasing strength and muscle hypertrophy is a high degree of effort at the end of a set of repetitions with such effort achievable through moderate or even light resistance [22, 24, 25]. These findings and approach could make RT more appealing and accessible to demographic groups where prevalence is low [22]. However, RT's efficacy and *safety* depends within this effort-based approach on learning proper form (movement and attention control) [21, 22] for a dozen or more RT exercises to train the whole body and learning to reach a high degree of effort at the end of a set of repetitions, i.e., training to "momentary muscular failure" [26]. Common to any RT approach are learning and applying progression rules and becoming suitably conditioned to move from one exercise to the next one within a minimal inter-exercise interval (1–2 min) [14] to have a time-efficient protocol. These considerations pointed to an intensive initial "face-to-face" phase, which in the Resist-Diabetes study involved twice per week supervised training (1 trainer, 1 to 2 trainees) for 3 months, with each training session requiring 30–40 min. By way of contrast, simpler, well-known behaviors such as increasing walking to meet minimal physical activity guidelines did not require this intensive instructional phase of intervention [27]. RT also is time and place specific, with attention, as noted, to form, degree of effort, and safe and logical progressions [21, 22]. Continued benefits are dependent upon persistently performing RT, i.e., maintenance [16, 22]. From a social cognitive theory (SCT) perspective [28], effectively acquiring the knowledge, skills, and self-efficacy for RT involves a series of planned mastery experiences (modeling, practice, corrective feedback). Maintenance of RT requires use of basic self-regulation skills to plan, implement, and track RT workouts, make logical adjustments to a protocol, and overcome barriers and use strategies for barriers endemic to RT and overall life circumstances [21].

After effective, intensive initiation of RT for improving glycemic control, strength, and body composition, the Resist-Diabetes trial focused on the comparative efficacy of low (Standard) and higher-dose and cost (SCT) interventions for long-term maintenance of RT. It was hypothesized that SCT would produce significantly better adherence and outcomes on primary measures than Standard [13]. This report focuses on behavioral, adherence, and maintenance data including corroborating data for adherence and workouts, participants' use of strategies for overcoming barriers, ratings of maintenance program components, treatment fidelity, and attendant costs for the two maintenance interventions. Preliminary outcomes for biomarkers are reported elsewhere [29, 30].

METHODS

The Resist-Diabetes study was approved by the IRB at Virginia Tech. The study involved four assessment points: baseline, months 3, 9, and 15; and 4 phases: initial, supervised RT (3 months); transition (3 weeks);

maintenance (6 months), and no contact (6 months). Participants were randomized to a maintenance condition after post-assessment, marking the end of the supervised training phase of the study.

Participants and recruitment–The Resist-Diabetes trial involved a 15-month intervention with women (73 %) and men (*N*=170), 50–69 years old, with a BMI of 25–39.9 kg/m^2, all fitting prediabetes criteria of either impaired fasting glucose (IFG; fasting glucose=95–125 mg/dl), impaired glucose tolerance (IGT; 2-h glucose=140–199 mg/dl) or both, from an initial assessment [13], plus a signed clearance form from a primary care physician. Participants primarily were recruited in four waves through newspaper ads, direct mail, and organizations' listservs. People responding to the ads first went to an information website and then after providing consent (*N*=1038), advanced to screening on another secure website. Screening questions were sequenced so that exclusion criteria appeared first. Given the main focus on assessing the maintenance of unsupervised training, those with additional health risks beyond prediabetes, likely requiring additional medical testing and possibly medically supervised exercise [13, 14] were disqualified. Exclusion criteria included BMI>39.9, <50 or >69 years old, smoking, any current chronic disease, and uncontrolled blood pressure, orthopedic problems limiting the ability to exercise, taking medications that affect energy metabolism, and, additionally, currently RT or meeting or exceeding ACSM's [14] physical activity and exercise guidelines.

Overall, 118 individuals were excluded for BMI, 92 for disease conditions, 58 for medications, 148 for currently engaging in exercise, 2 for smoking, 17 for not meeting age range; 261 individuals withdrew from the screening process or did not proceed through the process, 53 individuals were withdrawn from the process for lack of submission for medical clearance within 60 days, and 4 were denied medical clearance. After screening, individuals (*N*=285) meeting criteria and a medical clearance from a physician consented to a full baseline assessment which required about 3 h for 2 days in the lab/gym with the assessment for prediabetes criteria occurring on the first day of assessment to determine qualification. From this group, those individuals (*N*=170) meeting prediabetes criteria were enrolled in the 3-month supervised training phase of the study. At the baseline assessment, 111 individuals did not meet prediabetes criteria and 4 exceeded the BMI limit. After the 3-month phase and post-assessment, participants (*N*=159) were randomized to one of two conditions: social cognitive theory (SCT; *N*=79), or Standard (*N*=80). The mean age of participants was 59.5 years, 73 % were female, mean BMI was 33.0 kg/m^2, mean percent body fat (assessed using dual-energy X-ray absorptiometry, DXA) was 43.8 %, and mean waist circumference (WC) was 109.1 cm. Participants were well-educated (96 % some college or higher), primarily (93.5 %) Caucasian, and at baseline, 30 % reported they were retired from full-time work. There were no differences in age, gender distribution, ethnic/racial groups, or occupational status between those individuals qualifying or not qualifying at baseline assessment.

Approaches–Table 1 notes SCT elements and face-to-face and Internet-assisted components for both treatment groups, described below. As shown in Table 2, a number of approaches were used for treatment fidelity [31–33] following delineated procedures that then can be assessed for meeting treatment fidelity guidelines including those for the study design, training of staff, delivery of the treatments, receipt by participants, and enactment of resistance training in the lab/gym and in community settings [32].

Initial intensive supervised phase–All study participants engaged in the same initial, twice per week, 3-month RT phase in our lab/gym. All RT was supervised with one trainer for one or two participants and no more than two trainers and four participants in the lab/gym at one training time. All trainers had proper certifications and appropriate social skills. All trainers received a trainers' manual and role-played sessions with corrective feedback from staff before commencing to train participants. Each training session required 30–40 min. All participants received an 8-page manual describing the rationale, principles, and the specific techniques of RT within the study's protocol. The manual also was available on the Resist-Diabetes website.

The lab/gym included treadmills and stationary bikes for a brief warm-up before training and 12 Nitro-Plus Nautilus machines for training the entire body: leg press, leg extension, leg curl, calf raise, chest press, pulldown, shoulder press, row, seated dips, abdominal crunch, lower-back extension, rotary torso. The first several sessions involved *mastery experiences* for each exercise. This included a trainer demonstrating (modeling) an exercise, e.g., leg press; then a participant using the same exercise machine with minimal resistance; corrective feedback on form from the trainer; if needed, repeating the exercise movement with correct form; over the course of the first several sessions, establishing a safe range of motion (ROM) for each exercise; an appropriate resistance, and practice with reaching momentary muscular failure based on an inability to perform another repetition in appropriate form, and high ratings of perceived exertion [RPE; 34] at the end of each set of repetitions for each exercise. Participants also were instructed on how to set up each machine (e.g., seat position) for their proper range of motion and to choose the correct resistance. The RT evidence-based [22, 24] protocol involved one set on each of the 12 exercises using a repetition duration of 3 s for the concentric (raising) phase of the repetition and 3 s for the eccentric (lowering) phase of the repetition. When eight repetitions in the prescribed form and ROM could be performed for two consecutive workouts or two out of three workouts, the resistance for an exercise was increased by 5 %. After each exercise, trainers assessed participants' RPE and also provided verbal feedback using a 4-point scale on

Table 1 | Social cognitive theory components and program structures used by intervention groups

SCT constructs, program structure	SCT	Standard (limited contact after initiation phase)
Knowledge, information, self-efficacy	Simple principles of training and progression. Likely course of improvement. Issues in maintenance. Delivered in verbal and print form.	Simple principles of training and progression. Likely course of improvement. Issues in maintenance. Delivered in verbal and print form.
Self-regulation in session	Focus on form and effort; based on progress, plus repetitions and resistance; corrective feedback; plan next session.	Focus on form and effort; based on progress, plus repetitions and resistance; corrective feedback; plan next session.
Self-regulation outside session	Barriers/strategies approach on the Resist-Diabetes site for choosing strategies if barriers to RT. Report strategies, provide feedback, stay with or choose new strategies.	Brief print manual about barriers/ strategies.
Self-monitoring	Record each workout after it occurs plus can choose specific strategies on the Resist-Diabetes site; downloadable workout form.	Record each workout after it occurs on the Resist-Diabetes site; downloadable workout form.
Goal setting, feedback, planning	Receive automated tailored feedback on each session and suggested goals for each exercise. Plan and schedule the next workout all on the Resist-Diabetes site.	Generic information about the goal of RT 2×/week. Plan and schedule the next workout on the Resist-Diabetes site.
Ecological aspects	Continued assessment in follow-up contacts to develop if needed strategies for work and family responsibilities to facilitate RT.	Information included in brief print manual about barriers/strategies.
Expectancy to continue training scale	Continuous assessment on the Resist-Diabetes site of training expectancy 2×/ week and barriers and strategies.	No assessments or strategy selection.
Transfer of training—assess comfort in new facility and how well RT will fit schedule	Hands-on sessions in new facility. Instructions for how new machines work; comfort level in new facility; fitting RT into schedule.	One orientation session in the new facility and tips to continue.
Protocol—participants' modifications	Modifiable with feedback within limits to maintain or improve expectancy.	N/A
Continued contact (check-ups)	Faded contact with follow-up coordinator revolving around SCT constructs.	Limited faded didactic contact with the follow-up coordinator.

SCT social cognitive theory, *RT* resistance training

ROM, smoothness of the repetitions (no starts and stops), and smoothness of transitions (concentric to eccentric; eccentric to concentric) and described the rational for the rating and what could be improved. This feedback was provided for each exercise during all training sessions. A record of each training session was kept during this phase by the trainers on the Resist-Diabetes website.

In order to move onto the next phases (transition, maintenance) of the intervention, participants needed to attend and complete a minimum of 17/24 RT sessions (i.e., 71 % adherence) and complete post-assessment which was the same as the baseline assessment [13]. Adherence during the initial supervised phase was 92.9 % (22.3/24.0 workouts) for the 159 participants advancing to the next phase. Participants after this phase and post-assessment were randomized stratified by age, gender, and strength gain to condition: SCT or Standard.

Transition and maintenance phases–As shown in Tables 1 and 3, while both SCT and Standard were based on SCT, the SCT group received an appreciably higher dose of intervention, with considerably more interactions and tailoring than Standard. In the transition phase, SCT participants were engaged in a series of mastery experience sessions to learn how to use the Resist-Diabetes site and train on their own. These sessions included: (1) four sessions still within the lab/gym where they were provided guidance and then trained on their own and learned how to navigate the Resist-Diabetes website, (2) three sessions in the participant's new facility, training with the trainer to learn how to use the different machines, resistance, and ROM for each machine, (3) becoming comfortable in the new setting, including if the setting was crowded, the necessity of changing the order of exercises and not simply waiting a long time for a specific exercise machine to be available, (4) a session with the

Table 2 | Treatment and fidelity tactics

Domain	Tactics
Design	Manual-driven RT interventions based on SCT and specific SCT procedures through extended contact for each study condition with schedule and frequency of contacts preplanned; record of each planned session on the Resist-Diabetes site; review by outside experts; standardized assessments and SCT developed measures; specification of trainers' credentials; sufficient power to detect treatment effects; wave system of recruitment to match personnel. Capabilities and ability to adhere to assessment and treatment schedules.
Training providers	Trainers have appropriate certifications and adequate social skills; initial standard training of trainers to assure skill level; trainers' manual describing each procedure; session manuals; ongoing supervision and feedback to prevent "drift" throughout the trial of trainers; training of the follow-up coordinator.
Delivery of treatment	Scripted manuals; prompts for each session for trainers for points to be emphasized; process checklist after each session; random checks of trainers and coordinator by investigators; anonymous ratings by participants of trainers' technical and interpersonal skills; maintain staff enthusiasm in treatments via supervision; minimize contamination via separate materials for each treatment condition and by assignment of friends, relatives, and co-workers of participants. Automated reporting and feedback via the Resist-Diabetes site on sessions reported by participant after unsupervised training sessions in maintenance with tailored feedback for SCT and generic feedback for Standard.
Receipt of treatment	All participants receive training manual and hands-on training for 3 months that includes initial modeling of each exercise, corrective feedback to participant on each exercise, and ongoing ratings and feedback for each exercise for 3 months; receive instruction on principles of resistance training progression; hands-on instructions in electronic reporting and site use. All participants can perform each exercise with proper form, range of motion, and degree of effort. All participants can plan workouts and enter workout data. Participants receive manual and instruction respective to treatment condition for maintenance phase.
Enactment of treatment	All participants complete SCT or Standard transition sessions for training unsupervised in a community setting. All participants at the end of transition demonstrate can plan and report workouts on the program site.

participant training alone in the new facility, and finally, (5) reporting back in a non-training session in the lab/gym any barriers or issues for training alone at the new facility. Standard received: (1) one instructional session in the lab/gym covering site use and training in the new facility, (2) one, non-training orientation session in the new facility where appropriate resistance machines for the protocol were noted, (3) a session where the participant trained alone in the new facility, and lastly, (4) a non-training session in the lab/gym for reporting any issues or barriers for training in the new facility.

As noted, participants in both SCT and Standard conditions also received hands-on instruction for reporting and planning workouts on the Resist-Diabetes site. The recommended approach for reporting a workout was as soon as possible after a workout. All transition sessions were scheduled by staff via the Resist-Diabetes site, and their completion was recorded on the site. All new facilities had adequate equipment to perform the same protocol as in the lab/gym, but no facility had the same brand and line of equipment as the lab/gym. Every new facility had prescribed safety equipment and personnel trained for emergencies, and every facility agreed to allow the project trainers to train or instruct participants in their facility.

During the maintenance phase, SCT was scheduled for nine brief (15–20 min) follow-up contacts, bimonthly for the first 3 months and then once per month for the last 3 months. Contacts (check-ups) were first face-to-face with the follow-up coordinator and then were conducted by phone or Skype. All contacts revolved around RT workouts entered by the participant into the ID and password-protected Resist-Diabetes website, any barriers encountered, and the helpfulness of strategies used for a barrier. As established in the informed consent, study staff had access to participants' training records. Participants completed a series of "yes" or "no" questions about their ability to plan, schedule, and complete their RT workout. Participants then entered workout data including the exercises performed, resistance, and repetitions plus form and ratings of perceived exertion (RPE) ratings for each exercise. Tailored feedback on a workout and progress was provided to participants in a "report card" format, e.g., the planning of a workout and its scheduling, ability to marginally add resistance or repetitions to an exercise, and aspects of form such as ROM and RPE. Participants also completed a 10-point satisfaction rating with RT (1=Not at all; 10=Very) and an expectancy rating for the likelihood of continuing to RT twice per week (Scale: 1=Not at all Likely; 10=Extremely

Table 3 | Transition and maintenance procedures

Session for SCT	Procedures for SCT	Session for Standard	Procedures for Standard
1–2	Train with trainer and receive session feedback. Review training plan and goals for the day. Together, enter all training data into lab-gym computer on the Resist-Diabetes site. Enter expectancy rating. Problem solve for barriers. Enter strategies, if barriers. Collaboratively, plan next session with goals for each exercise. Receive feedback on workout based on plan and meeting goals by second session[a].	1	Meet trainer for initial didactic session at lab-gym. Receive manual on frequent RT barriers and typical strategies. Receive information about local health facilities and discuss options. Review general information available on study website[b].
3–4	Train alone with trainer present. Enter alone all training data in the Resist-Diabetes site in lab-gym and receive feedback based on plan and meeting goals. Plan next workout given progress[a].		
4	Choose facility with trainer to continue to train alone after transition phase[c].		
5–7	Train one-on-one with trainer in new facility. Focus on how new machines work plus comfort and ecological factors that can influence continued training[a]. Report from any access point to the Resist-Diabetes site training data and enter goals and schedule and plan for the next workout[c].	2	Meet with trainer for orientation session in new facility. Become familiar with environment and equipment. No hands-on training[a].
8	Train alone in the new facility[b]. Report training data to the Resist-Diabetes site. Receive feedback. Enter goals and plan for the next workout[c].	3	Train alone in the new facility[b].
9	Meet with trainer in lab-gym. No training. Review plans and goals for continued training. Review potential barriers and means to make minor protocol changes[b].	4	Meet with trainer in lab-gym. No training. Review progress, comfort level, and RT adjustments in new facility. Learn how to enter all training data and schedule, plan, and report workouts on the Resist-Diabetes site[b].
10–18	Briefly meet 2×/month for 3 months and then 1×/month for 3 months for check-ups with the coordinator face-face, phone, or Skype. Review all workout data, specific feedback received on the Resist-Diabetes site. Tailor, change, or retain strategies based on reported outcomes. Schedule and plan next contact session[c].	5–6	Briefly meet 2× during 6 months for check-ups with the coordinator face-face, phone, or Skype. Review the RT guidelines and general advice about RT. Schedule next contact session[c].

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[a] 60 min

[b] 30 min

[c] 15 min

Likely). A barriers/strategies sequence was triggered by a rating of <6 or a drop of 2 points from the previous rating. Specific barrier areas were noted as were relevant strategies. Subsequent data entry by the participant resulted in a query about the helpfulness of the strategy with the participant having the option of retaining the strategy or trying another strategy.

Participants' brief face-to-face, phone, or Skype check-ups with the follow-up coordinator revolved around these training records, barriers and strategies (if any), and additional information to decrease any barriers to continue to effectively RT twice per week. As noted, these brief check-ups occurred at first twice per month and then once per month for a total of nine contacts. To aid continuity of the contacts, the follow-up coordinator entered notes on the Resist-Diabetes site about each check-up into a participant's training file with the goal of making any changes to decrease barriers for training, increase self-efficacy, and optimize training. Over the next 3 months, the check-ups occurred once per month, for a total of nine individual sessions.

The Standard intervention involved considerably less contact (check-ups) and only limited use and generic feedback from the Resist-Diabetes website. Standard participants received a 4-page manual that reviewed the barriers/strategies approach but provided no tailored information. Participants met face-to-face, by phone, or Skype with the coordinator only twice during the follow-up phase (once every 8–10 weeks) for didactic check-ups primarily involving information about RT, frequently encountered barriers, and training strategies after a plateau is reached. Standard participants were expected to access the Resist-Diabetes site with their ID and password. However, their capabilities were restricted to planning, scheduling, and reporting workouts and they only received generic feedback, i.e., a reminder of the goal of resistance training twice per week. There also were no satisfaction and expectancy ratings, specific questions, or a barriers/strategies sequence. As with the SCT group, Standard participants could print out their workout plan.

No-contact phase–The maintenance phase lasted for 6 months, and then participants completed a full assessment identical to baseline and post-assessments. This was followed by a 6-month phase where there was no contact with participants in either group. Participants then returned for a complete assessment 15 months after baseline.

MEASURES

Time-line follow-back–Following an approach used in substance abuse programs [35], a time-line follow-back (TLFB) approach was used to assess RT adherence at the 9- and 15-month follow-up assessments. Participants were provided a calendar with the instruction of noting within the last 30 days, the day of each RT workout. A participant's score could range from 0 to 8; however, because a small percent of participants engaged in RT 3/week, these participants reported >8 workouts in the 30-day period. The TLFB was used as a primary measure of adherence because our own prior research [27] did not suggest high rates of planning and reporting of health behaviors to a site over extended periods (11–15 months).

Transition sessions–These sessions were those planned by the research staff for each participant and the number of those sessions attended by the participant.

Workouts planned, ratings, workouts scheduled and completed–These data are the workouts scheduled and reported to the Resist-Diabetes website during maintenance and no-contact phases by participants. SCT participants also indicated if a workout was planned or not planned and completed satisfaction and expectancy ratings.

Check-up appointments–Check-up appointments during the 6-month maintenance phase for SCT (9 appointments) and Standard (2 appointments) were all scheduled at the start of that phase for each participant. Check-ups could be performed face-to-face in the lab/gym or by phone or Skype. The duration of each check-up and the focus of the check-up was noted and recorded on the Resist-Diabetes site.

Barriers, strategies–These data are the barriers noted and strategies used by participants as reported to the coordinator for both SCT and Standard groups.

Treatment fidelity–The assessment of treatment fidelity entailed the match between recommended procedures across treatment fidelity domains [32] and those procedures performed in the Resist-Diabetes study.

Intervention costs–The costs do not include strictly research-related tasks, participant recruitment, assessments, the Resist-Diabetes website, or manual development, or participants' time to resistance train or to travel to the site, or health club membership [9, 36]. The initial lab/gym training setting is similar to what is available in health clubs, community centers or "Y"s'. The site and manuals can be used by different organizations. The current transition and maintenance approach could be used within the initial training facility for maintenance of training without a trainer or used, as in this study, to transition a person from one setting to another setting. Given these provisions, the costs for maintenance that were calculated only involved lab/gym costs for trainers, each health club visit by trainers, and each coordinator contact. The Resist-Diabetes site was developed to include all functions as noted for the SCT group. Those inappropriate for Standard participants, such as tailored feedback, were not functional for Standard participants.

RESULTS

Throughout all phases of the study, there were four serious though non-life-threatening adverse events reported while about 12,500 workouts, ~4000 supervised in the lab/gym and ~8500 alone in community settings, were performed. Data are reported for participants completing assessments through 9 months (N=138, SCT, N=68; Standard, N=70) and for 15 months (N=129, SCT, N=64, Standard, N=65). Major reasons for discontinuation from post-assessment involved scheduling conflicts for training and assessment and disinterest. No data are available for non-assessment

completers. However, estimates of adherence rates for the entire sample of participants (N=159), randomized after post-assessment, are provided with non-assessment completers assigned a score of 0.0 %.

Adherence–The TLFB showed that, at the 9-month assessment, SCT participants reported 6.2 (3.2) workouts in the last 30 days (77.5 % adherence) and Standard participants reported 5.8 (3.2) workouts (72.3 % adherence). At the 15-month assessment, SCT reported 4.3 (3.7) workouts (53.1 % adherence) and Standard reported 4.3 (3.7) workouts (53.1 % adherence). There were no significant differences between groups for reported adherence. Including non-assessment completers as having performed no RT sessions, adherence rates for SCT and Standard, at the 9-month assessment were respectively 66.7 % and 61.34 %, and for the 15-month assessments, were respectively 42.4 % and 44.3 %.

Transition sessions scheduled and completed–SCT participants were scheduled for 526 transition sessions and 453 (86.1 %) were completed. Standard participants were scheduled for 213 transition sessions and 162 (76.1 %) were completed.

Sessions planned and ratings–SCT participants reported a mean of 54.0 sessions that were planned based on prior workouts, representing 97.9 % of sessions reported. The mean satisfaction rating was 8.7 (0.9) and the mean expectancy rating was 9.3 (0.9).

Workouts scheduled and reported–The number of scheduled workouts was always just marginally greater than occurred workouts. From the end of transition to the 15-month follow-up assessment (~11 months), SCT participants reported a mean of 55.2 (31.2) workouts, range 0–113 while Standard participants reported a mean of 43.7 (31.8) workouts, range 0–103, a significant difference between conditions, (t(128)=1.99, p<0.05) (d=0.37). However, across both groups, participants with a mean TLFB score for 9 and 15-month assessments of <4 reported a mean of 24.8 workouts (range 0–66); for a mean score >4 but <7, 43.6 workouts (range 0–85); and for ≥7, 83.6 workouts (range 41–120). A decrease in scheduling and reporting workouts from maintenance through the extended contact phase closely followed the TLFB adherence reports. There was no other Resist-Diabetes required site use beyond those involved in planning and reporting workouts.

Check-up appointments–Of the 808 check-up appointments for both groups, 744 (92.1 %) were completed. Of the appointments, 268 (36.0 %) were conducted face-to-face, 473 (63.6 %) were conducted by phone, and 3 (0.4 %) were conducted by Skype. For the SCT group, 603 of 666 (90.5 %) planned check-ups were completed and for the Standard group, 141 of 142 (99.3 %) were completed. However, for the SCT group, only 145 of 603 (24.1 %) completed check-ups as planned, primarily in the earlier part of the maintenance phase, were face-to-face (of 9 planned check-ups), while for Standard 123 of 141 (87.2 %) completed check-ups were face-to-face (of 2 planned check-ups). The mean duration of a check-up was about 15 min.

Barriers–During nine follow-up contacts, SCT participants reported barriers. If a participant reported the same problem a second or third time, this was counted as one barrier for a participant. The most frequently reported barriers for not completing two RT sessions per week were travel for work or vacation (22.3 %), busy schedule and typical family responsibilities (21.71 %), and minor health-related issues (26.9 %). Barriers pertaining to the health club environment, motivation, or financial costs were minimal (12.4 %). The Standard group using the same counting rule in their two contacts reported a similar distribution; travel (18.9 %), busy schedule and family responsibilities (20.0 %), minor health issues (30.5 %), and only minimal reporting for health club issues (8.7 %).

Strategies–Using the rule as with barriers, a strategy was only counted once per participant even when reported by a participant for successive times. Of the strategies reported by the SCT group during follow-up contacts, 25.9 % involved planning and rescheduling workouts or going to the gym at an "off-peak" time; 42.0 % involved modifying the basic routine to reflect progress, prevent soreness, decrease boredom, or to personalize the routine; 11.8 % involved seeking the gym's staff or trainer help; 8.7 % involved going to the gym with a family member or friend, 9.3 % noted using a local or hotel gym when traveling; and 2.8 % reported listening to music while RT. For the Standard group, 31.6 % involved planning and rescheduling workouts or going to the gym at an off-peak time; 36.7 % involved modifying the basic routine to reflect progress, prevent soreness, decrease boredom, or to personalize the routine; 17.8 % involved seeking the gym's staff or trainer help; 7.6 % involved going to the gym with a family member or friend; 2.5 % noted using a local or hotel gym when traveling; and 3.9 % reported listening to music while RT. Across both groups, 29.4 % of strategies noted involved scheduling and planning, and 40.2 % involved modifying the basic routine. However, the primary strategies associated with adherence as assessed by the TLFB were planning and reporting workouts to the Resist-Diabetes web site.

Follow-up survey–A follow-up survey was sent by email to participants at the end of their respective follow-up phase. Participants were surveyed to assess which strategies or procedures were most helpful for continued RT, 2×/week, using a 10-point scale. From a list of 16 strategies and procedures, the following specific self-regulation strategies–Workout on Specific Times/Day=7.6 (2.9); Planning Workouts via the web site=7.8 (2.8); and Recording Workouts via the website=7.8 (2.9); and self-referent, affective strategies–Seeing How Improving=8.4 (2.2), Feeling Better Physically=8.9 (1.6), and Comfort in the Community Facility=8.6 (2.1), were rated as most important for continuing RT 2×/week. Continued personal contact with the follow-up coordinator was rated only somewhat helpful=6.6 (3.1). A similar pattern emerged for strategies helpful to return to RT after missing 5 or more consecutive workouts.

Use of automated barriers strategies–Use of the automated barriers/strategies component of the Resist-Diabetes site was cued for the SCT condition by expectancy ratings of <6 or a drop of greater than 2 points from a prior rating. As noted above, expectancy ratings were high (9.3/10.0) and this component was only used by 17 SCT participants, for 1–3 times, with a total of 31 uses. Of the 17 SCT users of this component, 12 indicated that this component was helpful.

Treatment fidelity–A plan for the assessment of treatment fidelity [32] contains 16 points for treatment design, 6 points for training providers, 9 points for the delivery of treatment, 5 points for the receipt of treatment, and 2 points for enactment of treatment. Of these 38 points, 34 points or procedures (89.5 %) were met (see also Table 2). Those not met included an a priori plan to assess treatment fidelity (Delivery of Treatment), multicultural factors considered in the development and delivery of treatment (Receipt of Treatment), assessing participants' training skills within the community facilities and not just the lab/gym, and ongoing assessment of these skills in the community settings (Enactment of Skills).

Costs–Using current personal trainer costs in our area, during the initial phase, each training session cost $50; 24 sessions × $50 = $1200. The direct trainer contact costs during the transition phase were assigned the same costs as during the initial phase. Sessions during transition that only required the trainer to be present and provide instructions to participants for the Resist-Diabetes site access were assigned a cost of $25. The value of the coordinator time involving for both groups reviewing prior records, the actual contact, and then recording notes on the website after each contact was assigned a value of $30 for each contact. The cost in personnel time for the SCT transition and maintenance phases was $595 per participant compared to $160 for Standard participants. These costs do not include a website for planning, scheduling, and reporting workouts.

DISCUSSION

It was initially hypothesized that SCT would produce significantly better outcomes than Standard [3], especially with its staged series of mastery experiences during transition, tailored feedback from the Resist-Diabetes site, and nine follow-up contacts. The SCT group did report to the Resist-Diabetes site a significantly greater number of workouts after the transition phase for the maintenance and no-contact phases (55.2) compared to the Standard group (43.7). However, this difference may reflect more site use by SCT to plan and report workouts compared to Standard given that reported adherence rates from the TLFB were virtually the same for both groups. The data suggest that *more may not be better*, i.e., a higher-dose intervention may not be required for maintaining RT with older adults with prediabetes once RT is well-established within an intensive, supervised SCT context. However, a number of caveats need to be underscored about lower-dose RT maintenance interventions including: (1) RT first is well-established within an intensive, supervised SCT context, (2) our behavioral outcomes primarily involve assessment completers and not non completers who dropped out after post assessment, (3) all Standard participants received a brief orientation to RT alone in the new facility, (4) an emphasis was placed on *persistence* by use of relevant strategies for common barriers (e.g., busy work schedule; plan 1 workout for the weekend), (5) simple modifications of a basic RT routine were approved while keeping to training principles (i.e., good form and higher RPE at the end of each set) to reflect progress and prevent soreness, (6) tools were provided for basic self-regulation strategies (plan, schedule, monitor, report workouts), and (7) there was continued but limited face-to-face contacts. Thus, within these conditions, subsequent interventions can use the less expensive, lower-dose, though still SCT-based, Standard intervention for maintenance, perhaps augmented by stepped care where barriers that are problematic receive immediate attention [12]. A caveat, again noted, is that the lower-cost maintenance phase was preceded by an intensive, supervised phase. An additional caveat is that of the strategies reported to the follow-up coordinator, it could not be discerned which ones were most associated with adherence. The data from the Resist-Diabetes site plus participants' reports at follow-up do suggest that continuing to plan and report workouts were most associated with adherence with adjustments made for other responsibilities, work-related travel, and vacations. Further, while efforts were made to assure treatment fidelity (Table 2) in design, training, delivery, receipt, and enactment, a particular limitation of this study is that no participants were in any way observed training in the non-supervised phases of the study. Only frequency of training was assessed through the TLFB and from reports of workouts on the Resist-Diabetes site. We do not know, for example, if form and the degree of intensity were retained. Future studies can consider real-time assessment of training in different facilities using Skype and similar technologies. Nevertheless, with these caveats, given only a minimal transition phase and two personal contacts and a very minimal generic web site with basic self-regulation strategies, it is possible that the Standard condition represents a minimal intervention needed to maintain RT outside a supervised context [37]. The Standard intervention also compares favorably for contacts on a yearly basis with the maintenance procedures used in years two and three of the Diabetes Prevention Program [DPP; 38], with this program considered a benchmark for the dose of intervention required to reduce the risk of Type 2 diabetes with a translatable lifestyle intervention. However, it is not yet clear if the adherence to resistance training achieved (~75 % as assessed by the TLFB) during maintenance is sufficient to reduce the risk for Type 2 diabetes comparable to the DPP.

The outcomes for the present study for SCT compared to Standard, however, also represent a "systematic replication" of a prior, completely Internet-based, health behavior intervention, "Guide to Health" that had a similar design and spanned the same duration but did not have an initial intensive, supervised phase given the focus on *simpler* behaviors [27]. Two versions of that program focused on guiding people in increasing steps per day in a pedometer-based program and improving targeted food consumption, such as increasing servings per day of fruits and vegetables. The enhanced version had considerable tailoring of the program's content, goals, and feedback based on participants' reporting and progress, while the basic version was entirely generic. However, both versions involved planning, goal setting, monitoring behaviors, and reporting behaviors and both programs produced and then maintained about the same changes in physical activity and nutrition. The commonality of the two versions was the *most basic self-regulation strategies* that appeared, as in the Resist-Diabetes study, sufficient to maintain health behavior changes over an extended period.

However, an important qualifying and concluding point revolves around our reported adherence rates that were higher in both groups with no difference between groups at the 9-month assessment, with reduced reported adherence at 15 months, also with no difference between groups. Except for interventions where active components span years [7], there is minimal evidence of maintenance of effects once all program-based contact has ended. The outcomes for the Standard group point to an approach that appears translatable, useable by different organizations and settings, and consistent with the continual care model [6]. The approach can use lower-dose, lower-cost contacts, and incorporate stepped care [12]. Extra attention and support can be signaled by responses to simple questions or ratings on readily accessed systems. Help can quickly be provided for problematic barriers. It then may be feasible for this approach to continue over extended periods, if not, indefinitely, matching what would be expected for continual medical care for any chronic disease or condition [1].

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