

Psychology & Health

ISSN: 0887-0446 (Print) 1476-8321 (Online) Journal homepage: www.tandfonline.com/journals/gpsh20

Testing mediator variables in a resistance training intervention for obese adults with type 2 diabetes

David R. Lubans, Ronald C. Plotnikoff, Mary Jung, Neil Eves & Ron Sigal

To cite this article: David R. Lubans, Ronald C. Plotnikoff, Mary Jung, Neil Eves & Ron Sigal (2012) Testing mediator variables in a resistance training intervention for obese adults with type 2 diabetes, Psychology & Health, 27:12, 1388-1404, DOI: 10.1080/08870446.2011.613471

To link to this article: https://doi.org/10.1080/08870446.2011.613471

Published online: 06 Sep 2011.

Submit your article to this journal

Article views: 977

View related articles

Citing articles: 9 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=gpsh20

Psychology & Health
Vol. 27, No. 12, December 2012, 1388–1404

Routledge
Taylor & Francis Group

Testing mediator variables in a resistance training intervention for obese adults with type 2 diabetes

David R. Lubans[a]*, Ronald C. Plotnikoff[a], Mary Jung[b], Neil Eves[b] and Ron Sigal[c]

[a]*Priority Research Centre in Physical Activity and Nutrition, University of Newcastle, Callaghan Campus, Newcastle, NSW 2308, Australia;* [b]*Faculty of Health and Social Development, University of British Columbia, Okanagan, Canada;* [c]*Faculties of Medicine and Kinesiology, University of Calgary, Calgary, Canada*

(*Received 18 April 2011; final version received 8 August 2011*)

A poor understanding of behaviour change mechanisms has hindered the development of effective physical activity interventions. The aim of this study was to identify potential mediators of change in a home-based resistance training (RT) program for obese individuals with type 2 diabetes. Obese individuals with type 2 diabetes ($N = 48$) were randomly allocated to either an RT intervention ($n = 27$) or a control group ($n = 21$) for the 16-week study period. The study sample included 16 men and 32 women and the mean age of participants was 54.4 (± 11.7) years. Participants in the RT group received a multi-gym and dumbbells and home supervision from a certified personal trainer. RT behaviour was measured using a modified Godin Leisure Time Questionnaire. Social-cognitive constructs were measured and tested in a mediating variable framework using a product-of-coefficients test. The intervention had a significant effect on RT behaviour ($p < 0.001$) and muscular strength ($p < 0.001$). The intervention had a significant effect on RT planning strategies ($p < 0.01$), which mediated the effect of the intervention on RT behaviour. The home-based RT program successfully targeted participants' RT planning strategies which contributed to their exercise adherence.

Keywords: intervention; resistance training; mediation; obesity; strength training

Introduction

A chronic imbalance between energy expenditure and energy intake at the population level has contributed to increased levels of obesity in many western countries (Flegal, Carroll, Ogden, & Curtin, 2010; Rennie & Jebb, 2005; Thorburn, 2005). Obesity is associated with a range of serious co-morbidities including insulin resistance and type 2 diabetes (Flegal et al., 2010). Both resistance training and aerobic exercise have been found to improve body composition and improve

*Corresponding author. Email: david.lubans@newcastle.edu.au

ISSN 0887–0446 print/ISSN 1476–8321 online
© 2012 Taylor & Francis
http://dx.doi.org/10.1080/08870446.2011.613471
http://www.tandfonline.com

glycemic control among individuals with type 2 diabetes (Eves & Plotnikoff, 2006; Sigal et al., 2007; Zanuso, Jimenez, Pugliese, Corigliano, & Balducci, 2010). Exercise interventions promote increases in muscular and aerobic fitness; both of these outcomes are highly correlated with improved glucose tolerance (Hills et al., 2010). A recent systematic review and meta-analysis concluded that structured exercise programs consisting of aerobic exercise, resistance training, or both combined are more effective in reducing HbA(1c) than physical activity advice interventions in this population (Umpierre et al., 2011). However, individuals living with diabetes often have difficulty adopting and maintaining physical activity behaviour changes (Sweet et al., 2009; Tudor-Locke et al., 2004) and improving exercise adherence in this group is clearly a research priority. As obese individuals are at a higher risk of injury and pain-related intolerance in weight bearing aerobic activity (Hills et al., 2010), resistance training interventions may be particularly attractive for this group.

Physical activity interventions developed in reference to a theory of behaviour change (e.g. Theory of Planned Behaviour, Social Cognitive Theory, Transtheoretical Model) appear to be more successful in changing behaviour than atheoretical ones (Dishman, Oldenburg, O'Neal, & Shephard, 1998; Michie & Abraham, 2004). Theory-based interventions are hypothesised to impact upon relevant cognitions, which in turn influence behaviour (Hardeman et al., 2005). Mediation analysis can be used to explore these hypothesised pathways, which may help to improve our understanding of behaviour change (Baranowski, Anderson, & Carmack, 1998). Testing mediator variables allows researchers to determine which components of an intervention were associated with behaviour change (Bauman, Sallis, Dzewaltowski, & Owen, 2002). However, few studies have successfully identified mediators of behaviour change in physical activity interventions (Lubans, Foster, & Biddle, 2008; Rhodes & Pfaeffli, 2010).

Mediation analyses can be conducted using a variety of statistical methods (e.g., Baron Kenny causal steps, product-of-coefficients and difference-in-coefficients), but they generally involve an action theory test, a conceptual theory test and a significance test of the mediated effect (MacKinnon, 2008). The action theory test examines the impact of the intervention on the hypothesised mediators (e.g. self-efficacy). The conceptual theory test explores the association between changes in hypothesised mediators (e.g. self-efficacy) and changes in the targeted behaviour (e.g. frequency of exercise bouts) controlling for the intervention effect. Finally, a simultaneous test of both action and conceptual theory tests is conducted to test the significance of the mediated effect.

Few studies have explored mediators of behaviour change in interventions among clinical populations and to the authors' knowledge, no previous study has examined potential mediators in a RT intervention for obese adults with type 2 diabetes. In their systematic review of mediators in physical activity interventions in non-clinical populations, Rhodes and Pfaeffli (2010) concluded that self-regulatory processes, such as goal setting and self-monitoring have the most effect on changes in physical activity. However, they expressed concern over the general null findings and identified the need for increased innovation and intervention fidelity. Even less is known about the mechanisms of behaviour change among individuals with type 2 diabetes. A recent short-term study (i.e. 1-month) found that self-efficacy mediated the effects of a print-based physical activity intervention in this population (Dutton et al., 2009). The Alberta Diabetes Home-based Exercise Resistance Training Study (ADHERES) evaluated the effects of a home-based resistance training (RT) program

for obese patients with type 2 diabetes and was based on Social Cognitive Theory (Bandura, 2004). The primary aim of the present manuscript is to identify mediators of RT behaviour change in ADHERES.

Measurement issues might explain why few studies have successfully identified mediators of behaviour change in physical activity interventions (Lubans et al., 2008; Rhodes & Pfaeffli, 2010). Physical activity is difficult to assess accurately (Sirard & Pate, 2001) and mediation analyses that include physical activity as the targeted outcome are limited by the reliability and validity of the measures used. Unlike habitual physical activity measures, physical activity recall questionnaires require participants to report their activity over a recent period of time (typically 3–7 days; Trost, 2007). This method relies heavily on the assumption that the period of assessment is an accurate reflection of their usual activity or their physical activity throughout the intervention period. However, studies have found substantial seasonality (Plasqui & Westerterp, 2004; Reilly & Peiser, 2006) and intra-individual variation in physical activity (Levin, Jacobs, Ainsworth, Richardson, & Leon, 1999; Mattocks et al., 2007), both of which might contribute to null findings. Alternatively, in exercise-based interventions, such as resistance training and aerobic programs, improvements in muscular fitness and cardiorespiratory fitness may be considered the targeted outcomes and both provide a reflection of exercise adherence over the study period. Consequently, a secondary aim of this study was to determine if the same psychosocial mediators could also explain changes in muscular fitness in the study sample.

Methods

Study design

This study reports secondary data from the Alberta Diabetes Home-based Exercise Resistance Training Study (ADHERES) (Plotnikoff et al., 2010). In brief, ADHERES involved a prospective, two-armed, randomised controlled trial. Following baseline screening and testing, participants were randomised to the RT group ($n = 27$) or a non-training control group ($n = 21$). All testing procedures were repeated following the 16-week intervention. Assessments were conducted by trained research assistants who were blinded to participants' group allocation at baseline and posttest assessments. Following the 16 week intervention, the adjusted difference between intervention and control groups for bench press was 9.3 kg (95% CI 3.7 to 15.0, $P = 0.002$), leg press was 41.0 kg (95% CI 15.1 to 67.0, $P = 0.003$) and upright row was 12.4 kg (95% CI 7.3 to 17.5, $P < 0.001$; Plotnikoff et al., 2010).

Primary outcome and power calculations

The primary outcomes of the ADHERES study were muscular strength and improved glycemic control (A1C). The study was adequately powered to detect a 33% increase in strength and 12.6% relative decrease in A1C, with 80% power and an alpha level of $p < 0.05$. The study was sufficiently powered to detect medium to large mediation effects using the distribution of the PROduct Confidence Limits for INdirect effects (PRODCLIN) program (Fritz & MacKinnon, 2007).

Participants and screening procedures

Sedentary, obese individuals [body mass index (BMI) ≥ 30 kg/m^{-2})] with physician-diagnosed type 2 diabetes were recruited from diabetes clinics at the University of Alberta Hospital, Edmonton, Canada and the local community. Patients were excluded if they had a BMI <30 kg/m^{-2}; uncontrolled blood pressure (4160/90 mmHg); known, unstable cardiovascular disease; severe osteoporosis and/or musculoskeletal limitations to RT. Individuals performing RT in the last 6 months were also excluded. Ethics approval received from the institutional review board and informed consent was obtained from all study participants. A detailed description of participation recruitment, screening and retention, along with a study flow diagram have been reported previously (Plotnikoff et al., 2010). In summary, 162 obese patients were screened, however 114 were excluded due to a variety of reasons (e.g. BMI < 30, did not return follow-up call, already doing resistance training, musculoskeletal problems). There were no statistically significant differences between the groups at baseline for any of the study variables or between completers and the seven participants (control $= 3$ and intervention $= 4$) who dropped out of the study.

Intervention

Details of the intervention have been provided elsewhere (Plotnikoff et al., 2010). In summary, individuals randomised to the RT group were provided with a multi-gym apparatus and dumbbells. The theoretical framework of intervention and the behaviour change strategies employed are described in Table 1. Participants' baseline scores were used to determine training intensity, which progressed throughout the 16-week program. A certified personal trainer supervised training in the early stages of the program to provide social support and ensure that all exercises were performed safely and within the prescribed intensity range. The frequency of sessions supervised by the exercise specialist reduced over the intervention period, with 18 of the 48 sessions being supervised.

Measures

The following assessments were conducted by trained research assistants:

Muscular strength

Muscular strength was assessed using standardised procedures (American College of Sports Medicine, 2000). After being familiarised with correct lifting technique, the participants performed the 1RM tests- seated chest press, seated row and a leg press. The three strength tests were performed using standardised commercial weight machine (Apex Fitness Equipment, Saanichton, British Columbia, Canada). Chest press, seated row and leg press 1RMs were added together to create a total strength score which was used in the analyses.

Resistance training behaviour

Participants were asked to report the number and duration of RT sessions completed in an average week using a modified version of the Godin Leisure Time

Table 1. Theoretical framework of intervention and behaviour change strategies.

SCT construct	Explanation of how intervention targeted construct	Behaviour change strategies included in intervention[a]
Intention to RT	Participants were asked and encouraged to plan their RT sessions by the PTs. Goal setting was established with qualified PTs.	* Prompt specific goal setting * Prompt intention formation
RT planning strategies	PTs encouraged participants to plan their RT sessions and self-monitor their behaviour to ensure that they completed all necessary sessions. This included the identification of strategies to overcome barriers and the formation of plans to overcome barriers.	* Provide information about behaviour health link * Prompt self-monitoring of behaviours * Barrier identification
Task self-efficacy	Participants performed RT sessions with PTs, who also demonstrated the target behaviours. PTs corrected participants' technique and provided feedback on performance.	* Model or demonstrate the behaviour * Graded tasks
Scheduling self-efficacy	In addition to the scheduled PT visits, participants were asked and encouraged to schedule their own RT sessions and self-monitor their behaviours. Training logs were kept by the participants, and the qualified PTs checked and ensured the completion of the logs during home visits.	* Prompt self-monitoring of behaviours
Barrier self-efficacy	Participants were encouraged to identify barriers to RT and were offered strategies to overcome these barriers by PTs. The PTs also provided advice on injury prevention and modification of the exercises if participants experienced pain/soreness or injury.	* Barrier identification
Outcome expectations	Participants were provided with information of the benefits of RT by the PTs. PTs prompted self-reflection on RT performance and potential benefits.	* Provide information about behaviour health link * Information on consequences
Social support	PTs provided social support and encouragement for participants. PTs encouraged participants to elicit social support from significant others.	* Plan social support or social change * Model or demonstrate the behaviour

Notes: SCT = Social Cognitive Theory; RT = resistance training, PT = personal trainer.
[a]Adapated from behaviour change taxonomy developed by Abraham and Michie (2008).

Questionnaire (Godin & Shephard, 1985). The number and duration of RT sessions were multiplied to create the outcome variable mean minutes in RT/week.

Social cognitive variables

Validated measures assessing the following social-cognitive RT constructs were used: intention (Plotnikoff, Courneya, Trinh, Karunamuni, & Sigal, 2008), RT planning strategies (Ziegelmann, Lippke, & Schwarzer, 2006), task self-efficacy (Rodgers & Sullivan, 2001), scheduling self-efficacy (Rodgers & Sullivan, 2001), barrier self-efficacy (Plotnikoff, Trinh, Courneya, Karunamuni, & Sigal, 2009), outcome expectations (Plotnikoff et al., 2009) and social support (Plotnikoff et al., 2008). The constructs along with a description of the scales, number of items, sample items, psychometrics and published sources are reported in Table 2.

Analysis

Statistical analyses were completed using PASW Statistics 17 (SPSS Inc. Chicago, IL) software and alpha levels were set at $P < 0.05$. Marginally significant ($0.05 < p < 0.10$) results are noted. Analyses were conducted using the intention-to-treat principle and baseline observation carried forward was used for data missing at 16-week posttests. Unstandardised regression coefficients are reported in the results section. A product-of-coefficients test was used to assess single mediator models using ordinary least squares regression. The product-of-coefficients test involves an action theory test, a conceptual theory test and a significance test of the mediated effect and has good statistical power in small samples (MacKinnon, Fritz, Williams, & Lockwood, 2007). Change in the variables of interest (i.e. RT behaviour, muscular strength and potential mediators) were computed by regressing posttest values onto their respective baseline values to create residualised change indices.

An overview of mediation analysis is provided in Figure 1. In the first step, the total effect of the intervention on RT behaviour was estimated by regressing RT behaviour onto treatment condition (intervention or control; C coefficient). The second step was the action theory test which involved regressing the potential mediators onto treatment condition (A coefficient). The third step was the conceptual theory test which involved regressing RT behaviour onto treatment condition (C′ coefficient) and mediators (B coefficient). Finally, the asymmetric confidence intervals were used to test the significance of the product-of-coefficients (AB) using Mackinnon and colleagues PRODCLIN program (MacKinnon et al., 2007). For a variable to satisfy the criteria for mediation, it must be associated with the treatment condition and RT behaviour and the 95% confidence intervals (CI) for the product-of-coefficients (AB) must not include zero. The proportion of the total effect that was mediated was also calculated ($AB/(C' + AB)$). Bivariate correlation was used to examine the relationship between changes in RT behaviour and muscular fitness.

Results

Overview

The study sample included 16 men and 32 women. The mean age of participants was 54.4 (11.7) years (Table 3). Means and standard deviations for raw scores are

Table 2. Description and psychometric properties of hypothesised mediator scales.

Hypothesised mediators	Description of scale	Range (No. of items)	Source	α
Intention to RT	Participants reported their intention to RT by responding to the following question: *On a scale of 0% to %100, how likely is it that you will weight train/resistance train regularly over the next 4 months?*	0 to 100 (1)	Plotnikoff et al. (2008)	N/A
RT planning strategies	Participants reported their concrete plans for a RT schedule. Example item: *I already have concrete plans on what to do if I miss a weight training session.* Scale: 1 = *Hardly true at all* to 4 = *Exactly true*	1 to 4 (4)	Adapted from Ziegelmann et al. (2006)	0.92
Task self-efficacy	Participants reported their confidence to complete RT sessions. Example item: *On a scale of 0% to %100, how confident are you in your ability to weight train once a week?*	0 to 100 (3)	Adapted from Rodgers and Sullivan (2001)	0.95
Scheduling self-efficacy	Participants reported their confidence to overcome barriers and complete RT sessions they have missed: *On a scale of 0% to %100, how confident are you that you can make up a missed weight training session?*	0 to 100 (3)	Adapted from Rodgers and Sullivan (2001)	0.91
Barrier self-efficacy	Participants reported their confidence about RT on a regular basis in a variety of adverse circumstances. Using the common stem: *In the next 4 months I am confident that I can weight training three times per week*. Example item: *When I am a little tired.* Scale: 1 = *Not at all confident* to 5 = *Extremely confident*	1 to 5 (13)	Plotnikoff et al. (2009)	0.97
Outcome expectations	Participants reported the extent to which potential outcomes of RT would influence their decision to weight train regularly. Example item: *Weight training regularly will lead to better control of my blood sugar.* Scale: 1 = *Not at all* to 5 = *Very much*	1 to 5 (6)	Plotnikoff et al. (2009)	0.96
Social support	Participants reported their level of social support for RT from significant others. Example item: *Most people in my social network want me to weight train regularly in the next 4 months.* Scale: 1 = *Strongly disagree* to 5 = *Strongly agree*	1 to 5 (3)	Plotnikoff et al. (2008)	0.79

Notes: RT = Resistance training; α = Cronbach's alpha derived from study sample. In all scales higher numbers represent more positive responses.

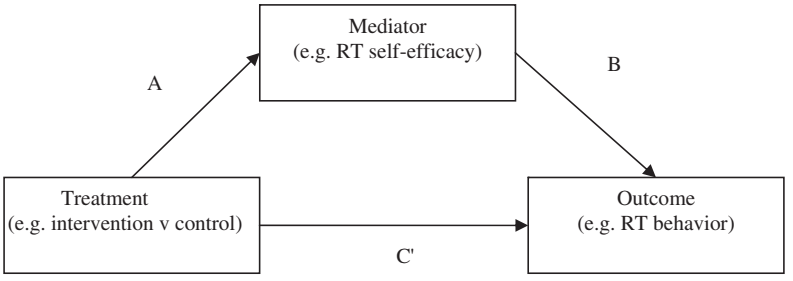


Figure 1. Overview of mediation including pathways and coefficients.

Table 3. Baseline characteristics of participants.

	Control ($n=21$)		Intervention ($n=27$)		Total ($N=48$)	
Characteristics	Mean	SD	Mean	SD	Mean	SD
Age (years)	54	±12	55	±12	54	±12
Gender						
Male, *n* (%)	8	38.1%	8	29.6%	16	33.3%
Female, *n* (%)	13	61.9%	19	70.4%	32	66.7%
Weight (kg)	100	±18	97	±27	99	±23
Height (m)	1.67	±0.11	1.65	±0.10	1.66	±0.10
BMI ($kg\,m^{-2}$)	36	±5	35	±8	36	±7
Chest press (kg)	45	±16	46	±22	46	±19
Seated row (kg)	55	±19	56	±21	55	±20
Leg press (kg)	99	±61	128	±86	116	±77
Total strength (kg)	200	±92	230	±124	217	±111
RT behaviour (mins/week)	13	±29	5	±16	8	±22

Notes: Means ± standard deviations reported; BMI = Body Mass Index; RT = Resistance training; Total strength = seated chest press + seated row + leg press.

reported in Table 4. Unstandardised coefficients and 95% CIs are reported in the results section. After 16-weeks, the intervention was found to have a significant effect on RT behaviour (C = 110.99, 95% CI = 78.28 to 143.72, $p < 0.001$) and overall strength (C = 63.83, 95% CI = 33.40 to 94.26, $p < 0.001$). The relationship between changes in muscular fitness and changes in RT behaviour was statistically significant ($r = 0.51$, $p < 0.001$).

Action theory test

Participants in the intervention group significantly increased their RT planning strategies (A = 0.72, 95% CI = 0.22 to 1.22, $p < 0.01$; Table 5). Changes in scheduling self-efficacy for RT were significantly associated with treatment condition (A = 19.24, 95% CI = 2.54 to 35.94, $p < 0.05$). The relationship between treatment condition and barrier self-efficacy was approaching statistical significance

Table 4. Baseline and 16-week posttest scores for strength and hypothesised mediators.

	Control groups		Intervention group		Total	
Variables	Baseline	16 weeks	Baseline	16 weeks	Baseline	16 weeks
Behaviour						
RT behaviour (mins/week)	13 ± 29	12 ± 27	5 ± 16	124 ± 68	8 ± 22	75 ± 78
Muscular strength						
Seated chest press (kg)	45 ± 16	45 ± 16	46 ± 22	55 ± 26	46 ± 19	51 ± 23
Seated row (kg)	55 ± 19	57 ± 21	56 ± 21	70 ± 28	55 ± 20	64 ± 26
Leg press (kg)	99 ± 61	94 ± 63	128 ± 86	175 ± 141	116 ± 77	140 ± 121
Total strength (kg)	200 ± 92	195 ± 94	230 ± 124	300 ± 190	217 ± 111	256 ± 134
Social-cognitive constructs						
Intention to RT	57 ± 34	48 ± 37	63 ± 40	58 ± 39	60 ± 38	54 ± 38
RT planning strategies	2.08 ± 0.84	1.92 ± 0.89	2.12 ± 1.11	2.67 ± 1.12	2.10 ± 99	2.34 ± 1.08
Task self-efficacy	72 ± 30	53 ± 35	80 ± 24	71 ± 35	77 ± 27	63 ± 36
Scheduling self-efficacy	64 ± 30	37 ± 29	74 ± 26	63 ± 35	70 ± 28	51 ± 35
Barrier self-efficacy	3.50 ± 0.86	2.69 ± 0.99	3.69 ± 0.96	3.36 ± 1.32	3.61 ± 0.91	3.07 ± 1.22
Outcome expectations	4.30 ± 0.90	3.84 ± 1.31	4.76 ± 0.41	4.19 ± 1.25	4.56 ± 0.70	4.03 ± 1.27
Social support	3.44 ± 0.95	3.09 ± 0.88	3.47 ± 1.31	3.05 ± 1.20	3.46 ± 1.15	3.07 ± 1.06

Notes: Means ± standard deviations reported; Baseline observation carried forward for missing data; Total strength = sum of 1RMs for seated chest press + seated row + leg press.

Table 5. Action theory test, conceptual theory test and significance of the mediated effect on RT behaviour.

Hypothesised mediators	Action theory test		Conceptual theory test		Significance of mediated effect		Proportion (%) AB/(C′+ AB)
	A (SE)	95% CI	B (SE)	95% CI	AB	95% CI[a]	
Intention to RT	6.89 (9.85)	−12.96 to 26.74	0.43 (0.25)	−0.07 to 0.94	2.96	−5.01 to 13.77	3%
RT planning strategies	0.72 (0.25)**	0.22 to 1.22	31.35 (8.39)**	14.44 to 48.27	22.57	6.09 to 44.53	20%
Task self-efficacy	14.31 (9.46)	−4.73 to 33.35	0.57 (0.24)*	0.08 to 1.06	8.16	−1.75 to 23.04	7%
Scheduling self-efficacy	19.24 (8.30)*	2.54 to 35.94	0.53 (0.28)	−0.04 to 1.10	10.20	−0.21 to 26.41	9%
Barrier self-efficacy	0.56 (0.32)	−0.08 to 1.20	16.63 (7.12)*	2.27 to 30.98	9.31	−0.70 to 24.83	8%
Outcome expectations	−0.15 (0.30)	−0.76 to 0.46	7.20 (7.84)	−8.59 to 22.99	−1.08	−7.09 to 3.35	<1%
Social support	−0.06 (0.26)	−0.59 to 0.48	3.07 (9.02)	−15.11 to 21.25	−0.18	−2.39 to 1.81	<1%

Notes: Control and intervention groups were coded as 0 and 1, respectively; RT = Resistance training; A = estimate of unstandardised regression coefficient of treatment condition predicting hypothesised mediators; B = estimate of the unstandardised regression coefficient of the hypothesised mediator predicting RT behaviour, with treatment condition included in the model; SE = standard error; 95% CI = 95% confidence interval; AB = product-of-coefficients estimate; C′ = effect of treatment on RT behaviour accounting for effect of mediator.

[a]95% asymmetric confidence intervals of the mediated effect calculated using the PRODCLIN program.

*$p < 0.05$; **$p < 0.01$.

(A = 0.56, 95% CI = −0.08 to 1.20, $p = 0.083$). The intervention did not impact upon RT intentions, task-self-efficacy, outcome expectations and social support.

Conceptual theory test

Controlling for the intervention effect, there was a significant positive association between changes in RT behaviour and changes in RT planning strategies (B = 31.35, 95% CI = 14.44 to 48.27, $p < 0.05$; Table 5). Changes in task self-efficacy (B = 0.57, 95% CI = 0.08 to 1.06, $p = 0.023$) and barriers self-efficacy (B = 16.63, 95% CI = 2.27 to 30.98, $p = 0.024$) were also associated with changes in RT behaviour. The association between changes in total strength and changes in RT planning strategies was statistically significant (B = 18.98, 95% CI = 0.94 to 37.02, $p < 0.05$; Table 6). Changes in task self-efficacy (B = 0.43, 95% CI = −0.03 to 0.89, $p = 0.064$), scheduling self-efficacy (B = 0.47, 95% CI = −0.06 to 1.00, $p = 0.078$) and barriers self-efficacy (B = 13.57, 95% CI = −0.53 to 27.67, $p = 0.059$) were marginally significant.

Mediated effects

Based on the product-of-coefficients test and the PRODCLIN asymmetric confidence intervals, changes in RT planning strategies mediated the effects of the intervention on RT behaviour (AB = 22.57, 95% CI = 6.09 to 44.53; Table 5). The proportion of the intervention effect mediated by RT planning strategies was 20%. The mediated effect attributable to task self-efficacy (AB = 6.15, 95% CI = −1.54 to 18.64), scheduling self-efficacy (AB = 9.04, 95% CI = −0.47 to 23.85), and barriers self-efficacy (AB = 7.60, 95% CI = −0.93 to 21.46), all approached statistical significance. Changes in RT planning strategies mediated the effects of the intervention on strength gains (AB = 13.67, 95% CI = 0.10 to 33.27; Table 6). The proportion of the intervention effect mediated by RT planning strategies was 21%. The mediated effect attributable to task self-efficacy (AB = 6.15, 95% CI = −1.54 to 18.64), scheduling self-efficacy (AB = 9.04, 95% CI = −0.47 to 23.85), and barriers self-efficacy (AB = 7.60, 95% CI = −0.93 to 21.46), were not statistically significant.

Discussion

The primary aim of this study was to explore mediators of RT behaviour in a home-based resistance training (RT) program for obese patients with type 2 diabetes. The intervention resulted in increases in RT planning strategies which in turn, mediated the effect of the intervention on behaviour. Changes in task self-efficacy and barrier self-efficacy were associated with changes in RT behaviour, but could not satisfy the criteria for mediation. A secondary aim was to determine if the same psychosocial mediators could also explain changes in muscular fitness in the study sample. The mediation results for muscular fitness were almost identical to those for RT behaviour, identifying the potential for using muscular strength as the dependent variable in mediation analyses in RT programs.

RT planning strategies was the only variable that satisfied the criteria for mediation. In the current study, participants in the intervention group increased their concrete planning for RT, including their strategies for overcoming barriers to

Table 6. Action theory test, conceptual theory test and significance of the mediated effect on muscular strength.

Hypothesised mediators	Action theory test		Conceptual theory test		Significance of mediated effect		Proportion (%) AB/(C′+ AB)
	A (SE)	95% CI	B (SE)	95% CI	AB	95% CI[a]	
Intention to RT	6.89 (9.85)	−12.96 to 26.74	0.29 (0.24)	−0.19 to 0.77	2.00	−3.55 to 10.09	3%
Intention to plan for RT	0.72 (0.25)**	0.22 to 1.22	18.96 (9.95)*	0.94 to 37.02	13.67*	0.10 to 33.27	21%
Task self-efficacy	14.31 (9.46)	−4.73 to 33.35	0.43 (0.23)	−0.03 to 0.89	6.15	−1.54 to 18.64	10%
Scheduling self-efficacy	19.24 (8.30)*	2.54 to 35.94	0.47 (0.26)	−0.06 to 1.00	9.04	−0.47 to 23.85	14%
Barrier self-efficacy	0.56 (0.32)	−0.08 to 1.20	13.57 (7.00)	−0.53 to 27.67	7.60	−0.93 to 21.46	12%
Outcome expectations	−0.15 (0.30)	−0.76 to 0.46	4.24 (7.53)	−10.93 to 19.42	−0.64	−4.78 to 2.54	<1%
Social support	−0.06 (0.26)	−0.59 to 0.48	−2.72 (8.44)	−19.73 to 14.29	0.16	−1.64 to 2.15	<1%

Notes: Control and intervention groups were coded as 0 and 1, respectively; RT = Resistance training; A = estimate of unstandardised regression coefficient of treatment condition predicting hypothesised mediators; B = estimate of the unstandardised regression coefficient of the hypothesised mediator predicting muscular strength, with treatment condition included in the model; SE = standard error; 95% CI = 95% confidence interval; AB = product-of-coefficients estimate; C′ = effect of treatment on muscular fitness accounting for effect of mediator.

[a]95% asymmetric confidence intervals of the mediated effect calculated using the PRODCLIN program.

*$p < 0.05$; **$p < 0.01$.

training, which mediated the effect of the intervention on behaviour. This finding is consistent with a recent review of mediators in physical activity interventions, which concluded that self-regulatory processes had the most evidence for mediation (Rhodes & Pfaeffli, 2010). For example, a recent study by Napolitano et al (2008) found that changes in behavioural processes mediated the effect for both print and telephone interventions on physical activity behaviour in a sample of inactive adults.

Changes in scheduling self-efficacy were positively associated with the intervention and changes in barrier self-efficacy approached statistical significance. However, none of the self-efficacy variables could satisfy the criteria for mediation as the posttest scores decreased in both control and intervention groups (decreases were larger in the control group) over the study period. As recommended, participants completed the questionnaires before physical assessments to prevent the actual process of assessment influencing their responses. This may have contributed to inflated baseline values and may explain the lower values reported at posttest. According to response shift theory (Sprangers & Schwatrz, 1999), changes in a measured variable (e.g. physical activity) are accompanied by changes in an individual's self-evaluation and/or internal standard (e.g. self-efficacy) (Vallance, Courneya, Plotnikoff, & Mackey, 2008). Participants in the current study were obese individuals living with type 2 diabetes and the 1RM testing protocols involved maximal efforts which may have been uncomfortable and unfamiliar to sedentary individuals. Therefore, when both intervention and control group individuals were assessed at posttest, their efficacy beliefs about completing RT reduced due to a more accurate understanding of the difficulty of training. Dutton and colleagues (2009) found that changes in self-efficacy completed mediated the effect of a physical activity intervention for patients with type 2 diabetes. However, unlike the current study, their study did not include physical assessments that could influence participants' ratings of the difficulty of completing the behaviour.

Alternate explanations for our failure to identify significant mediation effects in the ADHERES intervention include the following. First, the intervention strategies were not effective in changing the targeted constructs. While the intervention involved providing participants with a multi-gym and dumbbells, these were removed at the completion of the study. This might explain the reductions in self-efficacy observed among participants in the intervention group. Second, it is possible the targeted mediators were not the most appropriate mechanisms of change for the study population. There is a need to further explore the influence of socio-ecological mediators on behaviour change and these were not explored in the current study. Third, the null findings could be attributed to lack of variability in the measures and/or lack of sensitivity to detect change in the targeted constructs. Finally, our small sample size prevented us from detecting small mediation effects.

The mediation results for RT behaviour and muscular strength were almost identical and RT planning strategies mediated 20% and 21% of the intervention effect on behaviour and fitness, respectively. Muscular strength is a better measure of intervention effect in RT programs and evidence from the current study suggests strength could be used as the dependent variable in the mediation regression models. Rhodes and Pfaaeffli (2010) identified the need for novel approaches to examining mediators and using muscular strength as the dependent variable in RT interventions has a number of advantages. Muscular strength is not influenced by respondent bias and the precision of measurement is generally higher with good test-retest reliability (Harmon, Garhammer, & Pandorf, 2000). Furthermore, self-report and objective

behavioural data do not always reflect behaviour throughout an intervention period, while muscular strength gains will be directly related to the volume and intensity of training completed by the participants over the study period.

The intervention did not impact upon outcome expectations. This is not surprising as all participants would have volunteered for the study believing that RT was a worthwhile behaviour that could improve their health. Consequently, the baseline values for RT outcome expectancy were high for both control and intervention groups (>4.3/5). There is little evidence to suggest that changes in outcome expectancies mediate behaviour change in physical activity interventions (Rhodes & Pfaeffli, 2010). Beliefs about the benefits of physical activity may to certain extent, explain behaviour in cross-sectional studies, but individuals who have volunteered for a physical activity intervention may already be convinced of the value of such behaviour.

In the current study, a certified personal trainer supervised training in the early stages of the program to provide social support and ensure that all exercises were completed safely. In addition, participants were encouraged to elicit social support from significant others. While these strategies combined to enhance exercise adherence in the intervention, they were not successful in changing participants' perceptions of the social support they received from significant others. Identifying strategies to increase social support among sedentary individuals is challenging and novel techniques to achieve this outcome are clearly warranted. Task, scheduling and barriers self-efficacy might be important for behaviour change, but could not satisfy the criteria for mediation. Modeling RT behaviour and graded tasks were two behaviour change strategies used in the ADHERES intervention to enhance self-efficacy. While a personal trainer supervising the sessions in participants' homes may be an expensive strategy, the health care costs associated with treating obese adults with type 2 diabetes is substantial and arguably warrants this intervention component (Plotnikoff et al., 2010).

Although it is difficult to determine which intervention strategies were the most important for behaviour change in the ADHERES intervention, consistent with previous literature (Rhodes & Pfaeffli, 2010), teaching participants self-monitoring techniques holds considerable promise. More specifically, encouraging participants to formulate plans and identify techniques to overcome potential barriers are important skills and should be considered for future interventions. These behaviour change techniques are consistent with the concept of implementation intentions, whereby individuals consider in advance when, where and how they will achieve their stated goals (Gollwitzer, 1999), including, contingency plans when problems and barriers arise.

This study has several strengths that should be noted. First, this was a novel intervention that was evaluated with a unique population. Second, this was a high quality trial that adhered to the CONSORT statement (Moher et al., 2010). Third, mediation effects were explored using both behaviour and muscular strength as outcomes, helping to improve our understanding of the mechanisms of change in an RT program. Finally, MacKinnon and colleagues' PRODCLIN program (MacKinnon et al., 2007) was used to identify potential mediators in the study sample. Few studies have successfully identified mediators of behaviour change in physical activity interventions and product of coefficients tests, such as the PRODCLIN program, have been recommended for use in small samples (Fritz & MacKinnon, 2007). Despite these strengths, we acknowledge the relatively small

sample size that prevented us from detecting small mediation effects and testing multiple mediator models. In addition, the measurement of both behaviour and mediators relied on self-report, which may be biased by social desirability and limited due to lack of measurement sensitivity. The direction of causality cannot be determined in the current study and it is possible that behaviour influenced the mediators. Finally, the current intervention could be improved by the inclusion of a lifestyle physical activity component. Self-monitoring with pedometers has emerged as an efficacious strategy for increasing physical activity and improving weight status in adults (Bravata et al., 2007) and could be easily incorporated into the ADHERES intervention. This would provide additional opportunities for participants to engage in physical activity with significant others and may contribute to the sustained effectiveness of the program.

Conclusions

Our study has shown that a home-based RT program for obese participants with type 2 diabetes resulted in increased RT behaviour and muscular strength which were mediated by changes in RT planning strategies. These findings suggest that individuals working with obese individuals with type 2 diabetes should encourage them to make concrete plans and identify strategies to overcome barriers to training. Our study has also shown that including muscular fitness as the outcome variable is an appropriate strategy for identifying mediation effects in RT programs.

Acknowledgements

This study was funded by the Canadian Institutes of Health Research. Strategic Initiative in Excellence, Innovation and Advancement for the Study of Obesity and Healthy Body Weight. The Clinical Trials Protocol Registration System number is NCT00221208.

References

Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniquesused in interventions. *Health Psychology*, *27*, 379–387.

American College of Sports Medicine (2000). *ACSM's guidelines for exercise testing and prescription* (6th ed.). Baltimore: Lippincott Williams & Wilkins.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior, 31*, 143–164.

Baranowski, T., Anderson, C., & Carmack, C. (1998). Mediating variable framework in physical activity interventions: How are we doing? How might we do better? *American Journal of Preventive Medicine, 15*, 266–297.

Bauman, A.E., Sallis, J.F., Dzewaltowski, D.A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity – the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine, 23*, 5–14.

Bravata, D.M., Smith-Spangler, C., Sundaram, V., Gienger, A.L., Lin, N., Lewis, R., . . . , Sirard, J.R. (2007). Using pedometers to increase physical activity and improve health: A systematic review. *JAMA, 298*, 2296–3204.

Dishman, R.K., Oldenburg, B., O'Neal, H., & Shephard, R.J. (1998). Worksite physical activity interventions. *American Journal of Preventive Medicine, 15*, 344–361.

Dutton, G.R., Tan, F., Provost, B.C., Sorenson, J.L., Allen, B., & Smith, D. (2009). Relationship between self-efficacy and physical activity among patients with type 2 diabetes. *Journal of Behavioral Medicine, 32*, 270–277.

Eves, N.D., & Plotnikoff, R.C. (2006). Resistance training and type 2 diabetes. *Diabetes Care, 29*, 1933–1941.

Flegal, K.M., Carroll, M.D., Ogden, C.L., & Curtin, L.R. (2010). Prevalence and trends in obesity among US adults, 1999–2008. *Journal of the American Medical Association, 303*, 235–241.

Fritz, M.S., & MacKinnon, D.P. (2007). Required sample size to detect the mediated effect. *Psychological Science, 18*, 233–239.

Godin, G., & Shephard, R.J. (1985). A simple method to assess exercise behaviour in the community. *Canadian Journal of Applied Sport Science, 10*, 141–146.

Gollwitzer, P.M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist, 54*, 493–503.

Hardeman, W., Sutton, S., Griffin, S., Johnston, M., White, A., Wareham, N., . . . , Kinmonth, A.L. (2005). A causal modelling approach to the development of theory based behavior change programmes for trial evaluation. *Health Education Research, 20*, 676–687.

Harmon, E., Garhammer, J., & Pandorf, C. (2000). Administration, scoring and interpretation of selected tests. In T.R. Baechle & R.W. Earle (Eds.), *Essentials of strength training and conditioning* (pp. 287–317). Champaign, IL: Human Kinetics.

Hills, A.P., Shultz, S.P., Soares, M.J., Byrne, N.M., Hunter, G.R., King, N.A., . . . , Misra, A. (2010). Resistance training for obese, type 2 diabetic adults: A review of the evidence. *Obesity Reviews, 11*, 740–749.

Levin, S., Jacobs, D.R.J., Ainsworth, B.E., Richardson, M.T., & Leon, A.S. (1999). Intra-individual variation and estimates of usual physical activity. *Annals of Epidemiology, 9*, 481–488.

Lubans, D.R., Foster, C., & Biddle, S.J.H. (2008). A review of mediators of behavior in interventions to promote physical activity among children and adolescents. *Preventive Medicine, 47*, 463–470.

MacKinnon, D.P. (2008). *Introduction to statistical mediation analysis*. New York: Lawrence Erlbaum Associates.

MacKinnon, D.P., Fritz, M.S., Williams, H.G., & Lockwood, C.M. (2007). Distribution of the product confidence limits for the indirect effect: Program PRODCLIN. *Behavior Research Methods, 39*, 384–389.

Mattocks, C., Leary, S., Ness, A., Deere, K., Saunders, J., Kirkby, J., . . . , Riddoch, C. (2007). Intraindividual variation of objectively measured physical activity in children. *Medicine & Science in Sport & Exercise, 39*, 622–629.

Michie, S., & Abraham, C. (2004). Interventions to change health behaviours: Evidence-based or evidence-inspired? *Psychology & Health, 19*, 29–49.

Moher, D., Hopewell, S., Schulz, K.F., Montori, V., Gøtzsche, P.C., Devereaux, P.J., . . . , the CONSORT Group (2010). CONSORT 2010 explanation and elaboration: Updated guidelines for reporting parallel group randomised trials. *British Medical Journal, 340*, doi: 10.1136/bmj.c1869.

Napolitano, M.A., Papandonatos, G.D., Lewis, B.A., Whiteley, J.A., Williams, D.M., King, A.C., . . . , Marcus, B.H. (2008). Mediators of physical activity behavior change: A multivariate approach. *Health Psychology, 27*, 409–418.

Plasqui, G., & Westerterp, K.R. (2004). Seasonal variation in total energy expenditure and physical activity in Dutch young adults. *Obesity Research, 12*, 688–694.

Plotnikoff, R., Courneya, K., Trinh, L., Karunamuni, N., & Sigal, R. (2008). Aerobic physical activity and resistance training: An application of the theory of planned behavior among adults with type 2 diabetes in a random, national sample of Canadians. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 61.

Plotnikoff, R., Trinh, L., Courneya, K., Karunamuni, N., & Sigal, R. (2009). Predictors of aerobic physical activity and resistance training among Canadian adults with type 2 diabetes: An application of the Protection Motivation Theory. *Psychology of Sport & Exercise, 10*, 320–328.

Plotnikoff, R.C., Eves, N., Jung, M., Sigal, R.J., Padwal, R., & Karunamuni, N. (2010). Multicomponent, home-based resistance training for obese adults with type 2 diabetes: A randomized controlled trial. *International Journal of Obesity, 1*(34), 1–9.

Reilly, T., & Peiser, B. (2006). Seasonal variations in health-related human physical activity. *Sports Medicine, 36*, 473–485.

Rennie, K.L., & Jebb, S.A. (2005). Prevalence of obesity in Great Britain. *Obesity Reviews, 6*, 11–12.

Rhodes, R.E., & Pfaeffli, L.A. (2010). Mediators of physical activity behaviour change among adult non-clinical populations: A review update. *International Journal of Behavioral Nutrition and Physical Activity, 7*, 37. doi:10.1186/1479-5868-7-37.

Rodgers, W.M., & Sullivan, M.J.L. (2001). Task, coping, and scheduling self-efficacy in relation to frequency of physical activity. *Journal of Applied Social Psychology, 31*, 741–753.

Sigal, R.J., Kenny, G.P., Boulé, N.G., Wells, G.A., Prud'homme, D., Fortier, M., . . . , Jaffey, J. (2007). Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: A randomized trial. *Annals of Internal Medicine, 147*, 357–369.

Sirard, J.R., & Pate, R.R. (2001). Physical activity assessment in children and adolescents. *Sports Medicine, 31*, 439–454.

Sprangers, M.A.G., & Schwatrz, C.E. (1999). Integrating response shift theory into health-related quality of life research: A theoretical model. *Social Science & Medicine, 48*, 1507–1515.

Sweet, S.N., Fortier, M.S., Guérin, E., Tulloch, H., Sigal, R.J., Kenny, G.P., . . . , Reid, R.D. (2009). Understanding physical activity in adults with type 2 diabetes after completing an exercise intervention trial: A mediation model of self-efficacy and autonomous motivation. *Psychology, Health & Medicine, 14*, 419–429.

Thorburn, A.W. (2005). Prevalence of obesity in Australia. *Obesity Reviews, 6*, 187–189.

Trost, S.G. (2007). State of the art reviews: Measurement of physical activity in children and adolescents. *American Journal of Lifestyle Medicine, 1*, 299–314.

Tudor-Locke, C., Bell, R.C., Myers, A.M., Harris, S.B., Ecclestone, N.A., Lauzon, N., . . . , Rodger, N.W. (2004). Controlled outcome evaluation of the first step program: A daily physical activity intervention for individuals with type II diabetes. *International Journal of Obesity, 28*, 113–119.

Umpierre, D., Ribeiro, P.A., Kramer, C.K., Leitão, C.B., Zucatti, A.T., Azevedo, M.J., . . . , Schaan, B.D. (2011). Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: A systematic review and meta-analysis. *Journal of the American Medical Association, 305*, 1790–1799.

Vallance, J.K.H., Courneya, K.S., Plotnikoff, R.C., & Mackey, J.R. (2008). Analyzing theoretical mechanisms of physical activity behavior change in breast cancer survivors: Results from the Activity Promotion (ACTION) trial. *Annals of Behavioral Medicine, 35*, 150–158.

Zanuso, S., Jimenez, A., Pugliese, G., Corigliano, G., & Balducci, S. (2010). Exercise for the management of type 2 diabetes: A review of the evidence. *Acta diabetologica, 47*, 15–22.

Ziegelmann, J.P., Lippke, S., & Schwarzer, R. (2006). Adoption and maintenance of physical activity: Planning interventions in young, middle-aged, and older adults. *Psychology and Health, 21*, 145–163.