Physical Activity in the Management of Diabetes: Population-based Perspectives and Strategies

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ABSTRACT

This paper offers an overview of population-based perspectives and strategies related to the role of physical activity in the management of diabetes. Topics include the importance of physical activity promotion, need for theoretically driven approaches, individual-level population-based strategies and resistance training. Studies undertaken in the Physical Activity and Population Health Research Laboratory at the University of Alberta are presented as illustrative examples throughout. Recommendations and implications for research and practice are discussed, with a call for ecological approaches that recognize the inter-relationships between individuals and the multiple levels of their environments.

RÉSUMÉ

Ce compte rendu donne un aperçu des perspectives et des stratégies représentatives ayant trait au rôle de l'activité physique dans la prise en charge du diabète. Il porte entre autres sur l'importance de la promotion de l'activité physique, l'utilité de démarches théoriques, les stratégies représentatives adaptées à chacun et l'entraînement en résistance. Les études entreprises au laboratoire de recherche sur l'activité physique et la santé de la population de l'Université de l'Alberta sont présentées comme exemples. Le compte rendu traite des recommandations et des implications pour la recherche et pour la pratique clinique et préconise les démarches écologiques qui tiennent compte des liens entre les personnes et les divers niveaux de leur milieu.

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INTRODUCTION

Diabetes is a growing national and international public health concern (1). In Canada, 4.9 to 7% of the population over the age of 12 and 17% over the age of 64 are estimated to have diabetes. Ninety to 95% of these individuals have type 2 diabetes (2,3). Approximately 120 million people worldwide currently live with type 2 diabetes, and this figure is expected to climb to over 220 million by the year 2010 (4).

The increasing prevalence of type 2 diabetes is associated with the aging population, a significant rise in the prevalence of obesity and a sedentary lifestyle (1,4-5). Indeed, 60 to 90% of type 2 diabetes cases appear to be related to obesity or weight gain (6). Those who gain weight have significant deterioration of glycemic control. By comparison, a modest group mean weight loss of 6.8 kg was associated with significant improvements in glycemic control, fasting blood glucose (BG), insulin levels, high-density lipoprotein cholesterol and triglyceride levels at 1 year in adults with type 2 diabetes (6,7). In addition, moderate increases in physical activity and a weight loss of 5% of initial body weight can reduce the risk of developing type 2 diabetes by 58% (6).

The long-term complications of diabetes, such as micro- and macrovascular disease and neuropathy, can be delayed or prevented with appropriate intervention, including lifestyle changes (1,8). Lifestyle change strategies that combine diet, physical activity and behaviour modification are effective treatments for improving diabetic outcomes (5,9,10).

This paper provides an overview of the importance of physical activity promotion, the need for theoretically driven approaches, existing physical activity intervention strategies for those with diabetes (particularly type 2 diabetes) and resistance training. Current studies from the interdisciplinary Physical Activity and Population Health Research Laboratory (PAPH) are provided as illustrative examples throughout. Based within the Centre for Health Promotion Studies and the Faculty of Physical Education at the University of Alberta, Calgary, Alberta, Canada, PAPH focuses on individual-level and environmental-level theory and intervention development and testing across age groups (children, adults) and settings (clinics, schools, workplaces, communities) for both the prevention and treatment of diabetes and cardiovascular disease (CVD).

IMPORTANCE OF PHYSICAL ACTIVITY PROMOTION

Physical activity plays a key role in the management of type 2 diabetes, particularly glycemic control (1,11-13) and improvements in CV risk profile such as decreased hyperinsulinemia, increased insulin sensitivity, reduced body fat, decreased blood pressure (BP) and improved lipid profiles (14,15). Regular moderate physical activity and cardiorespiratory fitness are also associated with reductions in mortality of approximately 45 to 70% in type 2 diabetes populations (16). Moreover, regular moderate physical activity can decrease glycosylated hemoglobin (A1C) to a level associated with reduced risk of diabetic complications (12), and is therefore beneficial in delaying the onset of type 2 diabetes in high-risk groups (17,18). Three large randomized, controlled trials have unequivocally shown that lifestyle (physical activity and diet) interventions are effective for preventing or delaying the onset of type 2 diabetes (17,19-21).

In response to this evidence, the Canadian Diabetes Association (CDA) 2003 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada recommend that people with type 2 diabetes participate in moderate-intensity physical activity, such as brisk walking and biking, for at least 150 min each week, over at least 3 nonconsecutive days. Adults should accumulate over 4 h of physical activity per week (1). A new recommendation states that resistance training 3 times per week should also be incorporated into the management of all persons with diabetes (1).

Despite these guidelines, the majority of adults with type 2 diabetes are not active enough to achieve health benefits (22,23). Canadian data indicate 65% of individuals with diabetes are inactive (8), which is a greater proportion than the general adult population who are inactive (56%), according to public health guidelines (24). Physical activity research in the general population has established that without intervention, most people remain sedentary (25). The more successful physical activity interventions in general population studies emphasize lower-intensity activity (e.g. walking), use mediated delivery approaches (e.g. print, telephone counselling, internet) and employ theoretically based behaviour-change strategies (26).

There lacks, however, a broad population-based randomized, controlled trial with lifestyle interventions for the management of individuals who already have type 2 diabetes. Published studies on lifestyle change strategies for this population are very limited in their theoretical-based approaches (5,27,28) and in population reach (27). A "treatment gap" exists whereby physical activity interventions for the treatment of type 2 diabetes have primarily targeted individuals from clinical and community-based settings and typically focus on improved self-management in an individually or group-based tailored intervention, combined with drug therapy (5,29). Self-management interventions targeted to change diabetes self-care behaviours (e.g. physical activity and diet) demonstrate, at best, modest efficacy in the short term (30), while long-term assessments are very limited (5). Adherence to programs is also limited. Schneider and colleagues reported a 10% participation rate in physical activity for a behaviour-modification program in individuals with type 2 diabetes at 1 year (15). Further, many intervention studies for the management of type 2 diabetes do not report outcomes for physical activity behaviour change.

Given the beneficial effects of physical activity for those with type 2 diabetes and the low levels of participation in physical activity, Canadian research is urgently needed to define effective physical activity strategies tailored to this specific population (1). Population-based interventions in diabetes management should strive to be practical and feasible in a variety of settings, reach a large portion of the relevant population, be effective over the long term and be of relatively low cost (30). Very importantly, physical activity interventions should be theoretically driven.

Need for theoretically driven approaches

Whatever the mode of intervention delivery (e.g. print, telephone, computer), great potential exists in the employment of social-cognitive theories to explain behaviour change and drive interventions for type 2 diabetes populations (31,32). Approaches that incorporate social-cognitive theories are shown to be more efficacious than theoretically based interventions (30). However, it is estimated that only 12% of diabetes education and behavioural research employs a theoretical base (31).

Theoretical frameworks must be tested in populations with diabetes to identify factors that can be manipulated to achieve optimal behaviour change (31,33). Recent studies, for example, have shown that self-efficacy is an important construct that facilitates physical activity behaviour change (23,34). Identifying constructs and theories that can be used to increase the degree of behaviour change in type 2 diabetes populations will enable interventions to be tailored more effectively and ultimately increase treatment efficacy for lifestyle behavioural change (31,35). Further research that focuses on theory development and testing with the goal of increased physical activity behaviour change and maintenance of change is needed in this population (5,28,30,35).

Several theoretical perspectives have been applied to explain and predict physical activity behaviour change in the general population. Social-cognitive models most often investigated and supported in the exercise domain with the general population include the Transtheoretical Model (36), Theory of Planned Behaviour (37), Protection Motivation Theory (38) and Social Cognitive Theory (39).

To date, the application of such theories in adults with diabetes has been limited and exploratory in nature (23,40,41). These studies, however, provide some initial support for the application of social-cognitive theories among this population. For example, in a recent review of social-cognitive theory and diabetes exercise research, 13 studies (with sample sizes ranging from 46 to 185 individuals) examined the relationship between self-efficacy and exercise (41). Correlation and longitudinal studies revealed a statistically significant association between exercise behaviour and self-efficacy (41), yet the evidence as to whether this could be maintained over time was inconclusive (41).

Other social-cognitive constructs and items have been examined in the context of diabetes. Commonly cited barriers and related beliefs include lack of time, inconvenience, lack of others with whom to exercise, pain/discomfort, fear of complications, physical limitations and physical activity not viewed as a priority (42-44). Social support (45,46), outcome expectations (47) and outcome expectancy (48) are also associated with physical activity behaviour in this group. While these and other social-cognitive correlates and predictors are salient for both the general adult population and those with diabetes, there are, however, specific differences reported between these 2 groups regarding the magnitude of their association with physical activity behaviour (40). In particular, lower self-efficacy and higher threat perceptions are noted for those with diabetes compared with the general population (40).

Notwithstanding, there are a number of limitations in the current literature in this area. Social-cognitive theories have only been applied to individuals with diabetes for the promotion of aerobic-type activities. Further, studies often combine and do not differentiate between type 1 diabetes and type 2 diabetes subgroups, which is problematic as these groups may differ in their cognitive assessments, given the different etiology and management of the diseases.

PAPH example 1: ALEXANDRA study

Currently in the final phase of analysis, the Alberta Longitudinal Exercise and Diabetes Research Advancement (ALEXANDRA) study examined aerobic physical activity and its determinants in a prospective cohort of adults with diabetes, with follow-up assessments at 6 and 18 months. The research objectives were to 1) report the prevalence of exercise behaviour in terms of stage of exercise readiness and energy expenditure; 2) profile the sociodemographic, biomedical and psychosocial characteristics across physical activity levels; 3) assess the relative strengths of associations of sociodemographic, biomedical and psychosocial constructs with physical activity behaviour/energy expenditure and stage of physical activity behaviour change and quality of life; 4) determine if hypothesized baseline psychosocial constructs predict stage of physical activity behaviour change transition at 6 and 18 months; 5) examine the psychosocial and behavioural relationships between physical activity and the key behaviours of a multifaceted lifestyle regimen (i.e. diet, monitoring, medication and foot care); 6) examine the above objectives in the subset of First Nations men and women in the study cohort; and 7) examine the association between physical activity levels and healthcare resource utilization from Alberta Health and Wellness diagnostic, treatment and healthcare data records.

Albertans with diabetes (n=2318), recruited from the Alberta-Northwest Territories CDA Registry (n=1922) and through a random digit dialing protocol (n=396), completed baseline self-administered study instruments (23,40,49,50) on demographic, health/medical, quality of life, psychosocial (i.e. personality and core social-cognitive constructs of the Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behavior and Protection Motivation Theory) and behavioural (i.e. physical activity, diet, monitoring, medication and foot care) domains during May 2002. Alberta health records were also linked.

Of the type 1 diabetes group (n=697), 53.5% were female, mean age was 51.1 years (SD=17.1 years), mean BMI was 26.3 kg/m^2 (SD=4.4 kg/m^2), and 56.8% were classified as overweight or obese. Of the type 2 diabetes group (N=1614), 48.6% were female, mean age was 62.9 years (SD=12.1 years), mean BMI was 29.6 kg/m^2 (SD=5.9 kg/m^2), 79.1% were classified as overweight or obese, and 43.1% reported that physical activity participation was limited by a health condition, injury or disability. Compared with those with type 2 diabetes, people with type 1 diabetes were younger, had higher educational achievement and higher income. The demographic characteristics of our study generally reflect Canada's population with diabetes in terms of age and gender distributions (8).

Stage of physical activity behaviour change (51-53) revealed that 52.5% and 54.6% of type 1 and type 2 diabetes groups, respectively, were in "Action" or "Maintenance" stages for meeting public health guidelines. However, only 36.3% and 28.1% of those with type 1 and type 2 diabetes, respectively, were achieving recommended physical activity levels (49) when assessed with a more validated instrument of this behaviour (i.e. a modified version of the Godin Leisure-Time Exercise Questionnaire) (54). Using this tool, participants were categorized as "active" or "inactive" based on public health (55) and diabetes-specific (1,2) guidelines of achieving a minimum of 150 minutes of moderate-intensity activity per week (49). These poor participation rates attest to the urgent need to develop effective population health programs to increase physical activity. Further, stage-of-change measures appear to perform poorly in assessing mild (56) and moderate (57) (brisk walking pace) physical activity intensity levels, and should not be used as a measure to assess prevalence of physical activity in a given population.

Table 1 provides a percentage breakdown (by gender and age) of reported activities performed over a 2-week period during the fall of 2002 for individuals with type 1 diabetes (n=523) and type 2 diabetes (n=1193) who completed assessments at 6 months. The most prevalent leisure-time physical activity behaviour was walking for exercise (56% and 55% for type 1 and type 2 diabetes, respectively), while only 14% and 12% of type 1 and type 2 diabetes, respectively, engaged in weight-training (resistance) activity.

Perceived level of disability that would limit physical activity participation was a strong negative correlate with physical activity in the sample's type 2 diabetes group. This finding identifies the importance of promoting moderate-intensity activities (58) (e.g. walking, swimming, bicycling or resistance training), that can be done by individuals who are limited in the activities they can pursue. An important direction for future research is the inclusion of objective measurement techniques to assess physical activity behaviour (59) in this population.

While the health and medical correlates of physical activity from this cohort have been identified (49), the longitudinal assessment of the psychosocial variables (across the 4 social-cognitive theories examined) and environmental characteristics thought to influence physical activity patterns will soon be submitted for review. Results for the type 1 and type 2 diabetes groups have been examined separately and compared.

Individual-level population-based strategies

Individually tailored interventions are distinct from generic mass education approaches. With individual tailoring, participants receive personally relevant messages that lead to a higher level of specificity and more individualized feedback (60). In general population studies, tailored messages appear to be more efficacious than generic materials for producing change across various health behaviours, including physical activity (35,61).

Population-based tailored interventions can employ the use of print media, telephone counselling and internet/web-based mediums for behaviour change (60). These mediated interventions have the potential to reach a large number of individuals in a relatively cost-effective manner (60). Specific benefits of print media to promote behaviour change also include the promotion of self-initiated change, lower cost, ability to reach large numbers of individuals, lower staff and participant burden, minimized time barriers (as individuals can read the materials at their convenience) and use as a reference tool at a later date (60). There are disadvantages to print media, however, including difficulty determining dose-response, difficulty engaging the reader as personally relevant, lack of social support due to non-contact with a person and individuals often do not read the material.

One method of tailoring messages to the individual is to include telephone counselling as part of the population-based intervention (61). Telephone-based physical activity programs have achieved increases in physical activity similar to or greater than group- or facility-based programs over a short-term (61,62) and long-term basis (63,64). This may be particularly relevant to those living with diabetes, as telephone-mediated interventions appear to be effective in specialized populations, particularly those that may be highly burdened (e.g. visually impaired) (65,66). The telephone can also provide many of the advantages of face-to-face contact with less of the disadvantages; it costs less, requires less staff time, has a greater reach and is available in most households (67). There are disadvantages when compared with print, however, as telephone-mediated intervention is more expensive, increases staff burden and its added effectiveness may not be relevant once a physical activity program has been established (68). The efficacy of telephone-mediated interventions specifically in adults with type 2 diabetes has yet to be determined (30). Counselling techniques in the promotion of physical activity among individuals with type 2 diabetes has recently been examined and shown to be effective (69,70).

Pedometer and log use are practical, easy-to-use and low-cost strategies to increase the efficacy of physical activity interventions (71,72). In 1 of the first research studies to employ pedometers to increase walking in a small sample of individuals with type 2 diabetes, a goal of 10 000 steps per day was set. Participants exceeded this goal and on average walked 19 000 steps per day and achieved considerable improvements in insulin sensitivity (73). Results from other research suggest that an increase in the number of steps per day can result in decreased BP and reduced serum lipid profiles in healthy people (74,75). A recent study by Tudor-Locke and colleagues used pedometers as a physical activity intervention for individuals with type 2 diabetes as a baseline measure of physical activity, a measurement of number of

Table 1. Types of physical activities by total sample of type 1 diabetes and type 2 diabetes groups and by sex and age

Physical activity	***Type 1 diabetes group (n=524) %***					***Type 2 diabetes group (n=1193) %***				
	Total*	**Men†**		**Women†**		**Total***	**Men†**		**Women†**	
		≤65 years n=179	≥66 years n=65	≤65 years n=216	≥66 years n=64		≤65 years n=312	≥66 years n=313	≤65 years n=326	≥66 years n=242
Household chores	60	51.5	54.7	67.8	65.1	57	49.0	51.2	63.8	66.8
Walking	56	55.3	60.5	55.0	55.4	55	52.7	59.5	52.1	56.7
Yard work	36	43.9	43.0	33.6	15.7	35	47.1	39.0	26.5	24.8
Walking at work	28	36.7	10.5	33.6	3.6	19	33.0	10.9	20.4	7.4
Stretching exercises	25	19.8	17.4	30.8	27.7	23	19.4	21.3	23.6	27.5
Stair climbing for physical activity	18	14.3	22.1	19.4	22.9	19	11.9	18.2	17.8	29.9
Non-machine exercise at home	16	12.7	19.8	18.3	14.5	12	9.7	13.8	11.0	16.8
Playing with children	17	18.1	9.3	19.4	8.4	11	11.9	6.5	15.5	9.1
Jogging or treadmill	16	14.3	17.4	18.7	9.6	14	17.5	13.2	14.6	9.4
Weight training	14	14.8	11.6	17.0	4.8	12	14.8	14.3	9.2	8.7
Moving, pushing or lifting heavy objects at work	15	20.7	7.0	15.2	2.4	10	18.7	6.8	8.3	2.7
Machine exercise at home	14	11.8	22.1	12.8	12.0	13	10.0	16.1	11.7	14.1
Gardening	7	6.3	14.0	5.9	7.2	10	7.8	14.5	8.1	11.1
Exercise class or aerobics	8	3.8	4.7	11.4	8.4	7	2.9	6.5	9.7	11.7
Dancing	6	5.1	4.7	7.3	4.8	5	4.9	3.9	5.8	6.4
Bowling	7	5.1	4.7	8.0	6.0	4	2.9	5.7	3.6	5.0
Cycling	6	8.9	3.5	6.6	1.2	4	6.3	2.3	3.4	1.7
Swimming	5	5.1	1.2	7.3	3.6	4	3.4	3.6	6.5	3.7
Yoga or tai chi	4	3.4	0	4.8	2.4	3	0.5	1.6	3.8	5.0
Ice hockey	3	6.8	0	1.0	0	1	1.7	0.8	0	0
Golf	2	3.8	4.7	1.0	1.2	2	3.2	3.4	1.6	1.3
Ice skating	2	3.4	1.2	0.7	0	1	2.2	1.3	0.2	0
Basketball or soccer	1	3.0	0	0.7	0	0	0.5	0	0.2	0
Downhill skiing	1	2.5	0	0.3	0	0	0.7	0.8	0	0
Cross-country skiing	1	1.3	0	0.7	0	1	1.0	0.8	0	0
Squash or racquetball	1	2.5	0	0	0	0	0.5	0	0	0
Badminton	1	0.8	0	1.0	0	0	0	0	0	0
Tennis	0	0.8	0	0.3	0	0	0	0.5	0	0

*Total columns = % of total N reporting the behaviour
†Sex/age columns = % of column n reporting the behaviour
Data collected in fall 2002 (6-month follow-up)

steps taken over the course of the intervention, and as a device to facilitate goal setting, self-monitoring and feedback (76). There was an inverse, linear relationship between the increase in number of steps per day and A1C and fasting BG, suggesting that improvements in glycemic control occurred in subjects who increased to an additional 3000 steps per day above baseline (76). Consequently, pedometers can be used as a tool for motivation and self-regulation and as a measurement strategy for physical activity. Pedometers correlate well (r=0.80–0.93) with more expensive accelerometers, suggesting that they can provide an accurate measure of physical activity at a lower cost (76,77).

The investigation of these strategies, as population-based approaches for the treatment of type 2 diabetes, to date, has been rather limited. Further, the incremental/additive effects of combining such individual-level tailored strategies have yet to be examined in this population.

PAPH example 2: ADAPT

The large population-based Alberta Diabetes and Physical Activity Trial (ADAPT) aims to assess the incremental efficacy of 4 individual-level, behavioural-intervention strategies for the promotion of physical activity in the adult type 2 diabetes population. The strategies are designed to have a broad population reach and be practical, sustainable and affordable for potential public/population health standard care.

In this population-based, randomized, controlled trial, 300 individuals with type 2 diabetes were divided equally into 3 groups. Group 1 will receive standard CDA print materials about physical activity (and nutrition) every 3 months. Group 2 will receive CDA standard materials, a pedometer at baseline with step logs and a print-based module of physical activity information tailored to the individual's physical activity stage of readiness every 3 months. Group 3 will receive all the above interventions, as well as a tailored physical activity telephone counselling protocol over 12 months.

The information for the stage-matched materials and telephone messages is based on an integrated stage model developed by our team, operationalizing constructs across the key social-cognitive theories/items found to predict stage transition from the ALEXANDRA study. The primary outcome from this study is physical activity behaviour (assessed as energy expenditure and validated with accelerometers). Secondary outcomes include stage of progression/regression of behaviour change, social-cognitive measures across 4 major theories (i.e. Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behavior and Protection Motivation Theory), nutrition behaviour, quality of life, anthropometric assessments, fitness and biomarkers. All measures will be assessed at baseline, at the completion of the study (12 months) and follow-up (18 months). Satisfaction with the intervention materials/protocols and pedometers will be assessed at the completion of study and cost-benefit analysis will be conducted.

Resistance training

A promising new recommendation for those with diabetes is resistance training (1,58). The CDA (1), American College of Sports Medicine (78) and American Diabetes Association (79) recently updated their physical activity recommendations to include this important modality of exercise. Progressive resistance training, in which the resistance against the muscle is gradually increased over time (78), leads to gains in muscle mass. It is this increase, irrespective of fat loss, that is thought to cause the improvement in glucose disposal rate, glycogen storage capacity, GLUT4 receptors on skeletal muscle, insulin sensitivity and glucose tolerance (80-84). Resistance training can lower A1C (19), substantially improve insulin sensitivity (85), glycemic control (80-83,86) and quality of life (87). As an example of how these biological changes can impact on the individual's diabetes care regimen, a 16-week resistance training program led to 72% of the exercisers decreasing their antihyperglycemic medications, versus 42% of the control group increasing their medications (80).

A major appeal of resistance training as a form of diabetes treatment is its applicability for those with mobility limitations, as well as those requiring a staged-approach to achieving recommended levels for both resistance training and aerobic activity (88). As a significant number of adults with type 2 diabetes have decreased mobility due to excess weight, foot ailments, angina and poor balance (89), lifting weights or performing other forms of resistance training can provide a safe physiological stimulus with few complications. In some adults with specific clinical conditions (e.g. severe peripheral neuropathy or recurrent foot ulcerations), resistance training is preferable to aerobic exercise (81). Moreover, resistance training for some individuals may prove to be less daunting than going for a 30-min walk, as this population often associates aerobic exercise with shortness of breath, fatigue and possibly pain. In addition, because one receives immediate feedback when resistance training (e.g. amount one can lift, improvement since last workout), this form of physical activity may be more gratifying, and consequently more motivating, than other forms of activity. Providing a mode of physical activity that is achievable for inactive adults with type 2 diabetes is the first step in physical activity treatment. For some individuals, increasing confidence in performing resistance-training types of activity may result in the ability to begin performing aerobic activities. It is noteworthy that adherence to prescribed resistance-training sessions was reported to be approximately 90% over a period of 4 to 6 months in 2 randomized, controlled trials in older adults with type 2 diabetes (80,81); a higher rate than trials in this population assessing aerobic-type activities (15).

Despite the recommendation to engage in resistance training (55,78,90), the majority of adults with type 2 diabetes in the general population do not (49). In the only known population-based assessment of physical activity levels in adults with type 2 diabetes, Plotnikoff and colleagues (49) discovered that in a sample of 1193 individuals, only 12% were weight training or performing activities that would increase muscular strength (Table 1). Given the positive effect of resistance training on diabetes management, and its applicability despite the complications common to this condition (e.g. CVD, foot ulcerations, angina, at high risk for falling), it is concerning that so few individuals are choosing to engage in this type of activity. It is therefore necessary to also understand the behaviour change processes of resistance training (in addition to aerobic-type activities) in this population to guide the development and tailoring of effective and efficacious programs and strategies.

As discussed above, there has been limited research conducted on the social-cognitive predictors of physical activity in adults with type 2 diabetes, and no study to date has assessed the determinants of resistance-training behaviour in this population. Indeed there appears to be only 1 published study that explored resistance-training correlates in a sample of disease-free geriatrics (87). Predictors of this behaviour need to be understood in order to be appropriately tailored in subsequent interventions (91).

With the overwhelming majority of exercisers engaging in only aerobic forms of activity (Table 1), it is not surprising that many of the social-cognitive measures to predict general physical activity are more relevant for aerobic activity. For example, perceived barriers (Health Belief Model), perceived behavioural control and attitude (Theory of Planned Behaviour) towards an aerobic activity, such as walking, may be very different from the barriers, perceived control and attitudes towards resistance training. The items/scales from current questionnaires focus on aerobic activity (41); however, they may not adequately reflect the relationship between the various social-cognitive constructs and resistance-training behaviour when corresponding measures are applied to this modality. Testing theories/models with inappropriate measures would lessen the ability of such theories to explain this behaviour and guide interventions.

As there is no information to date on the determinants of resistance training in individuals with type 2 diabetes, the first step in designing a successful intervention to increase resistance training in this population is to develop valid and reliable measures that are specific to this mode of activity and population. These measures should then be used to assess the salient and strongest predictors of resistance training to guide appropriate interventions by operationalizing the appropriate theoretical constructs.

PAPH example 3: ADHERES

The goal of the Alberta Diabetes Home-based Resistance Exercise Study (ADHERES), is to develop an efficacious home-based resistance training (and aerobic) program that is low in cost and accessible over the long term. This project may prove to be an important first step for those inactive, obese individuals in pre-action stages of readiness, who are unwilling to attend a program based in a fitness-centre setting.

Inclusion criteria for this study are obese (BMI $\geq$30 kg/m^2) adults aged 40 to 65 with type 2 diabetes, with no previous medication contraindications who are currently not participating in any resistance-training activities.

Phase 1 of the study consisted of survey and focus-group work to identify psychosocial factors associated with resistance training and interest in and recommendations for a home-based fitness program. (A recently funded, 3-month longitudinal study will also examine the psychosocial predictors of resistance training in a randomized national sample of 500 adults with type 2 diabetes.) Phase 2 includes the development of the home-based program information led by an expert panel (practitioners, researchers and decision makers from health-related organizations) and the phase 1 results. The final phase consists of the implementation and evaluation of a 16-week home-based fitness program.

The home-based fitness program comprises 2 randomized groups: an intervention (n=27) and control group (n=27) with equal gender and age-range representation. The program involves progressive resistance-training techniques with a supplied and installed home gym with dumbbells (and individual counselling for recommended aerobic physical activity). Program supervision incrementally declines through the 16-week program. A trainer visits the participants' homes: 3 times per week during weeks 1 and 2, 2 times per week during weeks 3 and 4; once per week during weeks 5 to 8; and bi-weekly during weeks 9 to 16. Unsupervised training begins after week 2. Participants log their resistance sessions on their own, referring to types of exercises, duration and amount of weight used for each exercise. A full battery of social-cognitive, behavioural, anthropometric, fitness and biomarkers will be assessed at baseline and 16 weeks for both groups.

CONCLUSIONS

The importance of physical activity in the management of diabetes is empirically established. The importance of resistance training is now emerging. Although promising physical activity strategies incorporating print, telephone counselling or pedometer use for those with diabetes exist, broad-based randomized, controlled trials are required. Population-based interventions need to be based on social-cognitive theories adapted for use in this specific population. Issues of program adherence, reach (accessibility beyond clinics and community centres) and the lack of long-term assessments also need to be addressed. Moreover, physical activity research must differentiate between types of diabetes and specifically tailor programs to suit the different populations.

To this point, the discussion and illustrative projects presented have focused on the level of the individual. Interventions, however, ultimately must be focused at multiple levels, taking an ecological perspective. Ecological models recognize the role of the environment and the interrelationships between multiple levels (92-94), permitting the examination of the interaction between singular dimensions of the individual (e.g. biomedical, attitudinal, behavioural) with the multiple components of his/her context (e.g. social, organizational, community, public policy and physical environments). Behaviour is seen to be influenced by intrapersonal factors, interpersonal processes and primary groups, institutional factors, community factors, public policy and the physical environment (92-94). Interrelationships between the individual and his/her environment, as well as interactions within and between the various ecological levels, are considered. Hence, this model provides a mechanism through which the interaction of the singular dimensions of the individual with the multiple components of his/her life context can be examined. Our team has recently developed an organizational-based, ecological program standard and audit instrument for physical activity (95,96).

An important framework in guiding population-based interventions is Reach, Efficacy, Adoption, Implementation, and Maintenance (RE-AIM). The RE-AIM framework has been applied in the evaluation of several health behaviour change interventions, specifically those that target physical activity (97) and diabetes (98-100). The framework consists of 5 evaluative components that describe the overall population-based impact of an intervention (99). The RE-AIM framework focuses on the overall population-based impact by placing emphasis on both internal and external validity while considering both individual- and system-level outcomes and helps to prioritize public health issues, thus facilitating the translation of research into practice (99-101).

Population-based efforts require coordinated integrated teams composed of academics, governments, healthcare organizations, practitioners and the public. Such efforts are needed to build and test theories, interventions and programs, and develop databases to establish the timing and guide the proportional focus for each of the ecological levels towards the amelioration of the diabetes epidemic.

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