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Personalized Exercise for Adolescents With Diabetes or Obesity

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Abstract

Objective—This study examined adherence to a personalized, community-based exercise intervention by sedentary adolescents with type 1 or type 2 diabetes or those with obesity.

Research design and Methods—We conducted a pretest–posttest investigation to explore the application of an individualized exercise prescription based upon current fitness level for 39 adolescents (20 with type 1 diabetes, 9 with type 2 diabetes, and 10 obese) over 16 weeks in community settings. Subjects were recruited from a university-based pediatric endocrinology clinic in the southwestern United States. Adherence to the exercise prescription was monitored using accelerometers over the entire intervention period.

Results—Moderate-to-vigorous physical activity (MVPA) levels significantly increased over sedentary baseline values ($p < .001$), but the average of 42.5 ± 22.1 min/day of MVPA determined at the end of the study was still less than the recommended 60 min/day. Perceptions of health were significantly increased for the total group following the intervention ($p = .008$). For those with type 1 diabetes, there was a significant association between MVPA duration and percentage change in HbA_{1c} ($r = -.526$, $p = .02$).

Conclusions—Recruitment and retention of adolescent participation in daily exercise is challenging. Personalized approaches that include adolescent choices with family support and ongoing motivation can improve individual exercise adherence and a sense of personal health.

Keywords

adolescents; diabetes; obesity; exercise

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An epidemic of youth-onset diabetes is a present-day nemesis in the United States, threatening to place an even greater burden on the current health care system. New-onset cases of type 1 diabetes are increasing worldwide (Dabelea et al., 2007; Hummel et al., 2012; Karvonen et al., 2000). The prevalence of prediabetes and type 2 diabetes in adolescents is estimated to have increased from 9% to 23% in the United States between 1991 and 2008, an increase attributed to the increasing rates of overweight and obesity (May, Kuklina, & Yoon, 2012). With a growing number of young people confronted with a diagnosis of diabetes, personalized and effective approaches to therapeutic regimens are needed. Regardless of the type of diabetes, recommended treatment plans are based on individualized goals for self-management of pharmacological intervention, medical nutritional therapy, and regular exercise to maintain glycemic control, preserve quality of life (QoL), and minimize future complications, particularly those related to cardiovascular risks (American Diabetes Association, 2011). For adolescents, the daily responsibilities of diabetes management contribute to their personal struggles with adherence to treatment plans, including engaging in regular, daily exercise.

Despite the emphasis on exercise as a means for enhancing cardiorespiratory (CR) fitness, glucose control, and potential improvements in lipid profiles for adolescents with diabetes, intervention studies have mostly been limited to those with type 1 diabetes (Rachmiel, Buccino, & Daneman, 2007). These studies used small samples, provided minimal description of actual interventions, and found inconsistent results for the outcomes of glucose control, lipids, and fitness levels. Findings from some studies of youth with type 1 diabetes have shown beneficial effects of exercise interventions on glucose control (Herbst, Bachran, Kapellen, & Holl, 2006; Salem, Aboelasar, Elbarbary, Elhilaly, & Refaat, 2010), whereas others have not (D'Hooge et al., 2010; Roberts, Jones, & Fournier, 2002; Wong et al., 2011). Studies have shown that moderate-intensity, circuit-training interventions with these youths have improved CR fitness (D'Hooge et al., 2010; Heyman et al., 2007), fat-free mass (Heyman et al., 2007), and their perception of well-being or QoL (D'Hooge et al., 2010). However, in a recent review of the beneficial effects of physical activity in children, adolescents, and adults with type 1 diabetes, the authors indicated that it is still unclear what duration and intensity should be recommended and what outcomes should be expected (Chimen et al., 2012).

Although a substantive body of published exercise interventions for adolescents with type 2 diabetes has not been available, studies in adults with type 2 diabetes have shown that regular exercise improves CR fitness, hyperlipidemia, and glucose control (Balducci et al., 2009; Zois et al., 2009). For obese adolescents who are at risk for developing type 2 diabetes, supervised aerobic exercise interventions have resulted in improved lipid profiles (Ferguson et al., 1999; Kang et al., 2002) and increased CR fitness (Gutin et al., 2002). Cross-sectional research in adolescents and young adults without diabetes has indicated that higher amounts of moderate-to-vigorous physical activity (MVPA), with greater emphasis on vigorous activity, are associated with better CR fitness and more favorable heart rate variability profiles, particularly cardiac vagal modulation (Gutin et al., 2005; Soares-Miranda et al., 2011). Diminished cardiac autonomic function, as indicated by heart rate variability, is a well-established marker for poor prognosis in persons with diabetes (Maser,

Mitchell, Vinik, & Freeman, 2003; Vinik, Maser, Mitchell, & Freeman, 2003), lending support to the importance of regular exercise in this population.

Although some research relying on self-reports indicates that adolescents with type 1 diabetes engage in levels of physical activity similar to those of healthy peers (Fainardi et al., 2012), other evidence points to less regular physical activity among this population (Sarnblad, Ekelund, & Aman, 2005; Valerio et al., 2007). Less active lifestyles warrant heightened concern about self-management, since approximately 30% of youth with type 1 diabetes are overweight or obese (Sandhu et al., 2008).

All too often, health professionals in the clinical setting are uncertain regarding how to approach the topic of incorporating and sustaining regular exercise into the daily routine of adolescents with diabetes or those who are at risk for developing diabetes due to obesity. The primary aim of the present investigation was to determine the overall level of adherence to recommended levels of MVPA in response to a novel, 16-week, community-based personalized exercise prescription (PEP) intervention with adolescents who had not previously been actively engaged in physical activity and who had type 1 or 2 diabetes or who were obese and at risk for type 2 diabetes. We also examined the effects of the PEP intervention on clinical and QoL outcomes. Clinical outcomes included glucose control (HbA_{1c}), lipid profiles, body mass index (BMI) *z*-scores, CR fitness (VO₂ peak), and heart rate variability (HRV).

Methods

We used a pretest–posttest design in this exploratory study. The exercise intervention was based on the current fitness level of each adolescent. Participating adolescents identified personal exercise preferences among a number of choices, and parents supported these preferences. Preferences for exercise were based on available personal and community resources as well as restricted grant funding to supply necessary exercise supplies and equipment. The institutional review board at the University of Arizona approved the study. We recruited all adolescent participants and their parents from the pediatric diabetes clinic located at the University of Arizona Medical Center. Parents provided Health Insurance Portability and Accountability Act authorization and informed consent; adolescents provided personal assent.

The PEP intervention model was based on social cognitive and family systems theories. According to social cognitive theory, the intentional behaviors of adolescents are affected not only by personal choices but also by those of others. Thus, enlisting parental assistance and highlighting shared beliefs can help to produce desired results. In families with an adolescent member who has diabetes, the daily regimen of glucose control through medication adherence, dietary choices, and exercise necessitates planning, organization, and dedication to a healthy lifestyle. Social cognitive theory suggests that parental modeling to promote maturity assists in developing youth competency in interpersonal skills and healthy behaviors. Along with study procedures, we described the PEP intervention model in detail in a previous publication (Faulkner, Michaliszyn, & Hepworth, 2010). In brief, exercise prescriptions were aerobically based (60%–75% of predicted peak heart rate derived from

fitness testing) and included activities in which the adolescents had expressed an interest. These activities could be conducted at a gym facility, a park, a school, the participant's home, or all of the above. Examples of selected activities included calisthenics, kick boxing, dancing, cycling, walking, and Dance Dance Revolution (Konami, Japan). We provided the appropriate equipment and community resources (e.g., gym membership or dance videos) to participants at an average cost of US\$175 per adolescent. The exercise programs were designed around each adolescent and family's schedules. Programs were thus individualized to include smaller bouts of activity (~10 min) accumulated throughout the day or sustained bouts of activity with the goal of achieving 60 min of exercise per day. We conducted home visits bimonthly to review each participant's perception of her or his exercise program, level of adherence, exercise intensity, and any hypoglycemic events. Motivational strategies included reviewing accelerometry data on the laptop during the home visit to identify trends in activity patterns, complimenting success as well as discussing any barriers to goal achievement and ways to minimize them with the teen and parent. None of the youth with diabetes reported experiencing a hypoglycemic event during his or her participation in the intervention.

Inclusion criteria were (a) having a diagnosis of either type 1 or type 2 diabetes or age- and gender-adjusted BMI 95th percentile, (b) being 12–19 years old, and (c) having a parent willing to participate in approximately 30 min of physical activity daily, such as walking, to serve as a role model. Exclusion criteria were (a) being in a grade level more than 2 years below age appropriateness, (b) having diabetes as a secondary condition, (c) having any known cardiac defects, (d) already engaged in regular exercise or sports, or (e) being pregnant at the time of screening (confirmed via urine testing).

At the time of recruitment and enrollment, teens were screened with the 7-Day physical activity recall instrument (Sallis, Buono, Roby, Micale, & Nelson, 1993) to ensure that they were not already actively engaged in regular physical activity. A parent was also screened with the Physical Activity Readiness Questionnaire (Canadian Society for Exercise Physiology, 1994) to ensure that there were no known cardiovascular or musculoskeletal contraindications for participating in a moderate level of physical activity.

All baseline and postintervention data were collected at the research suite of the University of Arizona, College of Nursing. Fasting laboratory blood samples for lipid profiles, glucose, and HbA_{1c} assays were collected via finger stick. Immediately following blood sample collection, participants had a light breakfast prior to fitness testing. Adolescents who were not using pump therapy were instructed to bring their insulin supplies with them to administer their typical dose following breakfast. CR fitness testing was performed with participants with diabetes if fasting glucose levels were <250 mg/dl. Gender- and age-adjusted BMI percentiles and z-scores were computed using the Children's BMI-Percentile-for-Age Calculator, published by the United States Department of Agriculture/Agricultural Research Center (Children's Nutrition Research Center, Houston, Texas, <http://www.bcm.edu/cnrc/bodycomp/bmiz2.html>).

Measure

Level of MVPA Adherence—Adolescents were asked to secure an Actigraph™ Accelerometer (model GT1 M, Pensacola, Florida) on their right hip with an elastic belt during waking hours for at least 5 days/week over the 16-week intervention for the collection of objective physical activity measurements. Raw accelerometer data were used to calculate age-specific energy expenditure using a prediction equation developed by Freedson, Pober, and Janz (2005). Energy expenditure is expressed in metabolic equivalents (METs). MVPA frequency was defined as the percentage of days over the intervention period in which an adolescent achieved a minimum of 10, 30, or 60 accumulated minutes of MVPA (Faulkner et al., 2010). Activity measured at an MET of 3.0 is the minimum for moderate-intensity activity, while that which involves a MET of 6.0 is considered to be vigorous intensity (U.S. Department of Health & Human Services, 2008). In addition to MVPA frequency, the average daily minutes and intensity (METs) of MVPA were also computed. Accelerometry data were downloaded approximately every 2 weeks during the home visits by research staff, at which time the adolescent and parent could view the adolescent's activity level using Actigraph software on a laptop. Any revisions to the personalized exercise plan and development of strategies to motivate the adolescent to continue working toward her or his exercise goals were completed during the home visit.

The target for exercise adherence by the adolescents was at least 60 min of MVPA on at least 5 days per week over the 16-week intervention. Although current guidelines for adolescents recommend 60 min of MVPA daily (Silverstein et al., 2005; U.S. Department of Health and Human Services, 2008), we set a more realistic goal of 5 days per week so as not to overwhelm youth who were not accustomed to regular physical activity. We sought to track physical activity data over all 16 weeks in contrast to most studies on physical activity, which have included an average of only 7 days of such data (Trigona et al., 2010; Troiano et al., 2008).

Cardiorespiratory fitness—CR fitness (VO₂ peak) was measured using a Viasys™ Oxycon Pro metabolic cart (Jaeger-Viasys Healthcare, Hoechst, Germany) and cycle ergometer (Ergo-select 100®, Ergoline, Bitz, Germany). Each adolescent completed the McMaster protocol based on height- and gender-specific workload (Bar-Or & Rowland, 2004). Relative VO₂ peak (mL/kg/min) was determined by averaging the last 15 s of oxygen consumption obtained with a respiratory exchange ratio above 1.0. Each adolescent's exercise program was based upon a goal of reaching at least 60% of the maximum heart rate obtained during fitness testing. Adolescents were taught how to measure their radial pulse to assess heart rate during exercise.

Heart rate variability—HRV was measured continuously over 24 hr using a three-channel Vision 5 L Digital Holter recorder with a sampling rate of 200 samples/s and the Vision Premier Holter Analysis System Software, Version 3.41 (Cardiac Science, Bothell, WA). Ambulatory holter recorders were applied during pretesting and posttesting, following an approximate 30-min cool down period at the completion of fitness testing. Swimming and showering were not allowed while participants wore the monitors. Research assistants retrieved the monitors during home visits. Procedures for HRV analysis have been published

previously (Faulkner, Quinn, Rimmer, & Rich, 2005). Both frequency and time domain analyses of R-R interval variation were computed. Power spectral analysis provided estimates of the spectral density of specific frequency bandwidths, representative of parasympathetic and sympathetic modulation (Schumacher, 2004). Time domain analysis uses differing computations of the standard deviation of the beat-to-beat change in heart rate based on sinus R-R intervals over time (Cowan, 1995). Frequency and time domain measures are defined in the note to Table 1 later in this article.

Laboratory Measures—Lipid profiles were determined with the CardioChek™, and HbA_{1c} values were obtained with the DCA2000®+ Analyzer. The CardioChek P•A (Polymer Technology Systems, Inc., Indianapolis, IN, www.quickmedical.com/Polymer/) is a handheld clinical analyzer designed to run a variety of tests on whole blood using disposable test strips. The CardioChek P•A has established accuracy with clinical cut points set by the Cholesterol Reference Method Laboratory Network (Polymer Technology Systems, 2003). The DCA2000® + Analyzer provides accurate and reliable HbA_{1c} results for values between 2.5% and 14.0% (DCA 2000+ Analyzer Operating Manual, Bayer Corporation, Elkhart, IN).

Diabetes QoL—Psychosocial outcomes were examined by measuring disease-specific QoL with the Diabetes Quality of Life Measure for Youth (Ingersoll & Marrero, 1991). The instrument is composed of a 17-item Diabetes Life Satisfaction scale (comprising 7 items that are disease specific and 10 items that relate to general life satisfaction), a 23-item Disease Impact scale, and an 11-item Disease-Related Worries scale. Each item is scored on a scale of 1 to 5 (1 = *never or very unsatisfied*, 5 = *all of the time or very satisfied*). A general, single-item self-rating of overall health based upon a 4-point Likert-type scale with higher to lower scores indicating excellent to poor is also included in the instrument. For those who were obese, we used only the general life satisfaction subscale. Original Cronbach's α reliabilities for the subscales ranged from .82 to .85 (Ingersoll & Marrero, 1991). For this study, the α reliabilities ranged from .79 to .85.

Statistical Analysis

Data analyses were completed using PASW Statistics®, Version 18.0 (SPSS, Inc., Chicago, IL). Analysis of variance (ANOVA) was used to examine differences in adherence to the exercise intervention based upon the frequency of performing at least 10, 30, or 60 min of MVPA per day. The effect of the intervention on clinical and QoL outcomes was examined by conducting 3 × 2 ANOVAs to determine the group main effect, the time main effect, and the Group-by-Time interaction. The group main effect explored differences among the type 1, type 2, and obese groups collapsing over time. The time main effect explored differences from pre- to postintervention, irrespective of group. The Group-by-Time interaction identified whether pre- to postintervention differences existed among the three groups.

Results

We approached 105 adolescents for recruitment; 20 refused and 23 did not meet eligibility criteria. Of the 62 adolescents whose parents consented and who provided assent, 7 were

excluded following screening and 5 withdrew prior to pretesting, leaving 50 who enrolled. The final sample size of those adolescents completing all phases of the study (i.e., pretesting, intervention, and posttesting) was $N = 39$, reflecting a 63% completion rate for those originally enrolled. Reasons for adolescents to not complete the study ($n = 11$) were as follows: (a) lost interest in the exercise program ($n = 7$), (b) problems with family support ($n = 2$), (c) disliked wearing the accelerometer ($n = 1$), and (d) diagnosed with aortic stenosis ($n = 1$).

The final sample was comprised of nearly equal number of males and females in the type 1 and obese groups, with primarily females represented in the type 2 group (see Table 2). There were no differences in age or baseline self-report of average minutes of MVPA among the three groups. As expected, BMI z -scores and waist circumference values were higher in both the type 2 and the obese groups compared to those with type 1 diabetes. Duration of diabetes was longer for those with type 1 versus type 2 diabetes. Greater relative CR fitness was noted at baseline in those with type 1 diabetes versus those with either type 2 diabetes or obesity.

Medication regimes for the three groups were as follows: (a) for those with type 1 diabetes, 12 were on pump therapy and 8 received multiple daily injections; (b) for those with type 2 diabetes, 1 was on insulin injections, 3 received insulin injections and metformin, 3 received metformin only, and 2 were managed with diet and activity only; and (c) for those who were obese, 3 were receiving metformin with the remainder on no pharmacological treatment.

The average daily accelerometer wear time, days of accelerometer data, percentage of days in which a minimum of 10, 30, or 60 min of MVPA were performed, daily MVPA duration, and MVPA intensity (METs) are reported in Table 3. Those with type 2 diabetes wore the accelerometer significantly fewer hours per day compared to those with type 1 diabetes or those who were obese. However, the number of days the accelerometer was worn was higher for those with type 2 diabetes, although it was not significantly different from the numbers for the other groups. Adolescents in all the groups combined wore the accelerometer for an average of 73 days for 12.5 hr/day. Mean daily MVPA was 42.5 min/day with a mean intensity of 4.1 METS (moderate intensity). For the total group, daily MVPA min/day increased significantly over screening levels of 11.0 ± 12.4 min/day, $t(38) = -9.69$, $p < .001$, though we acknowledge the limitation of comparing objective and self-report measures.

On 70% of the days on which the accelerometer was worn, teens participated in at least 30 min of MVPA, while they participated in 60 min of MVPA on only 38% of those days. There was a trend for adolescents with type 2 diabetes to engage in 60 min of MVPA on fewer days than the other groups ($p = .09$).

We examined the effect of the intervention for each group and the total sample as well as any interaction effects (differences among the groups) on HbA_{1c}, lipid profiles, BMI z -scores, VO₂ peak, HRV, and QoL. Table 1 presents baseline and post-intervention values. For HbA_{1c} there was a significant group main effect, $F(2, 36) = 21.05$, $p < .001$. The Games-Howell post hoc test for unequal variances revealed that the obese group had

significantly lower HbA_{1c} values than the type 1 group ($p < .001$) and the type 2 group ($p = .003$), but the type 1 and type 2 groups did not differ from one another ($p = .434$). The lower HbA_{1c} values for the obese group were expected, providing confirmation that diabetes was not yet present.

For total cholesterol, there was a significant group main effect, $F(2, 33) = 4.071, p = .026$. The Gabriel post hoc test for equal variances revealed no significant differences among the groups. The largest difference was between those with type 1 (mean = 177 mg/dl) versus type 2 (mean = 134 mg/dl) diabetes ($p = .059$). For high-density lipoprotein (HDL), there was a significant group main effect, $F(2, 32) = 8.922, p = .001$. The Games-Howell post hoc test for unequal variances revealed that the type 1 group (mean = 46 mg/dl) had significantly higher HDL than the type 2 group (mean = 25 mg/dl, $p < .001$) and the obese group (mean = 34, $p = .009$). The obese group also had significantly higher HDL than the type 2 group ($p = .03$).

For BMI z -score, there was a significant group main effect, $F(2, 36) = 18.163, p < .001$. The Games-Howell post hoc test for unequal variances revealed that the type 1 group (mean = 0.81) had a significantly lower BMI z -score than the type 2 group (mean = 2.33, $p < .001$) and the obese group (mean = 2.33, $p < .001$). The type 2 and obese groups were not significantly different from one another.

For VO₂ peak, there was a significant group main effect, $F(2, 34) = 13.359, p < .001$. The Gabriel post hoc test for equal variances revealed that the type 1 group (mean = 32.9 ml/kg/min) had a significantly higher VO₂ peak than the type 2 group (mean = 20.7 ml/kg/min, $p < .001$) and the obese group (mean = 23.6, $p = .002$). Again, the type 2 and obese groups did not differ significantly from one another.

There were no significant findings related to QoL except a significant time main effect for the perception of personal health, $F(1, 36) = 8.001, p = .008$. For the entire sample, there was a significant increase in health perception from baseline (mean = 2.53) to postintervention (mean = 2.96). There were no significant differences in the changes from baseline to postintervention of outcome variables among the three groups.

Although we did not find that HbA_{1c} and VO₂ peak were significantly improved postintervention for either group with diabetes, we did find several significant relationships involving the physical activity intervention and percentage change in HbA_{1c} and VO₂ peak (see Table 4). For those with type 1 diabetes, there was a significant association between MVPA duration and percentage change in HbA_{1c} ($r = -.526, p = .02$) as well as a trend for percentage change in VO₂ peak ($r = .394, p = .09$). There was a trend among those with type 2 diabetes for improved CR fitness (VO₂ peak, $r = .635, p = .09$), with increasing frequency of performing at least 10 min of MVPA daily. There were no associations between MVPA frequency, duration or intensity, and VO₂ peak in those who were obese.

Discussion

Our primary aim in this investigation was to determine the level of adherence among participating adolescents to target levels of MVPA in response to a novel, 16-week,

community-based PEP intervention. To our knowledge, this longitudinal study is the first to track adherence to a PEP for adolescents who have either type 1 or type 2 diabetes or who are obese with risks for developing type 2 diabetes. The large amount of longitudinal accelerometry data we were able to collect demonstrates that time spent in MVPA for the total sample improved significantly, from a mean of 11.0 min/day (self-reported data) to a mean of 42.5 min/day during the course of the intervention. In comparison to studies that typically examine an average of 7 days of accelerometry data, the present study provides robust and valid reflections of activity trends among these vulnerable groups in response to a PEP intervention. Regarding our secondary aim of exploring the effects of the PEP intervention on clinical and QoL outcomes, we found evidence of improved glycemic control for those with type 1 diabetes who most frequently engaged in at least 30 min of MVPA/day during the intervention. Health perception as a measure of QoL improved for the total sample from pre- to posttest. In an earlier study of adolescents with type 1 or 2 diabetes, the author (M. S. F) noted a significant association of health perception with CR fitness (Faulkner, 2010).

Despite the use of individualized programs of activity based upon each adolescent's fitness level and exercise preferences, however, adolescents generally did not meet the study target of 60 min/day of MVPA. Although their level of activity over the course of the intervention was an improvement over their baseline sedentary activity, it was only slightly better than the values Gortmaker and colleagues (2012) reported for a nationally representative sample of adolescents without known diabetes. In their secondary analysis of accelerometer data collected over a 7-day period as part of the National Health and Nutrition Examination Survey conducted between 2003 and 2006, mean MVPA for 12- to 19-year-olds was 29.3 min/day $\pm$ 1.4 standard error (*SE*) and did not improve over the course of the study time frame. By contrast, 6- to 11-year-olds averaged 90.1 min/day $\pm$ 1.8 *SE* of MVPA.

Although we did not find significant differences in MVPA among the three study groups, mean frequency of performing at least 60 min of MVPA per day was 50% less in adolescents with type 2 diabetes compared to those with type 1 or those who were obese. In a previous study, the SEARCH for diabetes in youth study group also found that compliance with the MVPA recommendation among youths with type 2 diabetes was significantly lower compared with that of youths with type 1 diabetes or control subjects (Lobelo et al., 2010).

Despite our participants' failure to perform the recommended 60 min of MVPA per day, we did find evidence of improved glycemic control with increased daily duration and frequency of MVPA in adolescents with type 1 diabetes. Further support of the positive effect of regular physical activity was provided by a large cohort study conducted in Germany and Austria of 19,143 participants with type 1 diabetes ranging in age from 3 to 20 years in which a higher frequency of regular physical activity (defined as 30 min/day) was associated with better HbA_{1c} levels, without increasing the risk for severe hypoglycemia, regardless of sex or age group (Herbst et al., 2006).

We did not find improvement in lipid profiles following the intervention in any of our subgroups. However, strong evidence exists in support of improved cardiometabolic risk factors (i.e., lower triglycerides and higher HDL cholesterol) in youths who engage in more

cumulative minutes of daily MVPA, regardless of the amount of sedentary time, as reported in a recent meta-analysis of 14 studies from the International Children's Accelerometry Database (Ekelund et al., 2012). The findings of that meta-analysis were also independent of sex, age, and monitor wear time. Additionally, evidence from National Health and Nutrition Examination Survey data with children and adolescents revealed that there was no difference in the odds ratios associated with lower cardiometabolic risk factors based on whether higher amounts of accumulated MVPA min/day were performed sporadically or in bouts (Holman, Carson, & Janssen, 2011).

Although previous studies have indicated that increased amounts of physical activity are independent predictors of better fitness levels in youth with type 1 or 2 diabetes (Faulkner et al., 2005; Lukacs et al., 2012), fitness levels in the present study, as measured by VO_2 peak, did not change significantly from baseline to the end of the 16-week exercise intervention for the sample as a whole or for any of the three groups. Of particular concern is the low level of CR fitness we found in all the three groups, particularly in those with type 2 diabetes and those who were obese, whose values fell well below the average VO_2 peak for this age group (McArdle, Katch, & Katch, 2001). The lower fitness level we found in those with type 2 diabetes versus those with type 1 is consistent with our previous research (Faulkner et al., 2005, 2010). The values that we noted for the obese group were similar to those reported by Loftin, Sothorn, Warren, and Udall (2004).

We also found lower mean heart rate variability measures in youth with type 2 diabetes, though the differences among the groups were not statistically significant. This finding may have been confounded by the fact that participating youth were mostly female who tend to have lower HRV than males. However, in one of our earlier investigations we found that both gender and type of diabetes influenced total and low-frequency HRV (Faulkner et al., 2005).

Limitations of the study include the small sample size, particularly for those with type 2 diabetes or obesity alone, which likely contributed to the lack of power to find significant changes in the clinical outcome variables. Another possible factor in the absence of improved clinical outcomes is the predominantly moderate level of physical activity adolescents employed in this unsupervised, community-based program. This finding was particularly notable for the adolescents with type 1 diabetes who had higher fitness levels than the other groups yet exercised at the same level of intensity. In order to improve fitness and HRV indices, more intense levels of physical activity are required (Buchheit, Platat, Oujaa, & Simon, 2007). There were other factors that were beyond the scope of this study but that potentially affected clinical outcomes, including dietary changes and modification to medication regimes.

Conclusion

The question remains of how best to engage youth who have diabetes or are obese and at high risk for developing type 2 diabetes in regular daily physical activity that is moderate-to-vigorous in intensity. Although current guidelines for these youth recommend at least 60 min of aerobic activity daily, perhaps focusing on breaking up episodes of activity into 10-

20-, or 30-min bouts would be less challenging to adolescents who frequently identify multiple barriers to physical activity. Although we used accelerometers for data collection, practitioners could easily incorporate the use of much less expensive pedometers for assisting adolescents to track their more active lifestyle. A recent validation study of pedometer and accelerometer data revealed that a goal of 12,000 steps can be used with children and youth aged 6–19 years to approximate the recommended physical activity guideline of 60 min of MVPA (Colley, Janssen, & Tremblay, 2012).

The disheartening results of the recent TODAY trial for youths with type 2 diabetes (Zeitler et al., 2012) highlight the growing importance of type 2 diabetes prevention for this most vulnerable age group. In this trial, youth randomized to one of the treatment groups failed to meet treatment goals for glycemic control at approximately the following rates: 52% of participants receiving metformin, 47% of those receiving metformin and lifestyle intervention, and 39% of those receiving metformin with rosiglitazone.

Adolescents are suffering the consequences of increased weight and inactive lifestyles. It behooves all health providers to work closely with adolescents, their families, and communities to promote physical activity in a realistic manner that fits with their personal preferences and can occur in settings in which they reside. Successful efforts to increase physical activity in this population will help to minimize future disease burden and related complications.

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Table 1

Mean Baseline and Postintervention Measures.

Measure	Type 1 DM		Type 2 DM		Obese	
	Baseline	Posttest	Baseline	Posttest	Baseline	Posttest
HbA _{1c} (%)**	9.2 ± 1.9	9.5 ± 2.0	8.4 ± 1.8	8.4 ± 2.1	5.4 ± 0.3	5.4 ± 0.2
BMI z-scores**	0.86 ± 1.0	0.81 ± 1.0	2.4 ± 0.4	2.3 ± 0.5	2.4 ± 0.3	2.3 ± 0.4
Total cholesterol (mg/dL)*	177 ± 49	177 ± 65	137 ± 33	134 ± 43	138 ± 21	148 ± 56
LDL (mg/dL)	110 ± 31	109 ± 48	87 ± 19	87 ± 37	89 ± 20	98 ± 51
HDL (mg/dL)**	45 ± 12	46 ± 19	27 ± 7	25 ± 6	35 ± 10	34 ± 5
Triglycerides (mg/dL)	56 ± 46	47 ± 25	54 ± 27	50 ± 28	50 ± 23	58 ± 28
VO ₂ peak (ml/kg/min)**	33.0 ± 7.6	32.9 ± 8.6	20.2 ± 3.5	20.7 ± 5.3	23.2 ± 4.0	23.6 ± 5.3
Heart rate variability						
Total frequency	7.9 ± 0.9	7.8 ± 0.8	7.6 ± 0.6	7.6 ± 0.8	8.3 ± 0.9	8.0 ± 1.0
High frequency	6.3 ± 1.2	6.2 ± 1.2	6.0 ± 0.8	6.1 ± 0.8	6.8 ± 1.0	6.5 ± 1.1
Low frequency	6.7 ± 0.8	6.7 ± 0.8	6.4 ± 0.5	6.3 ± 0.6	7.0 ± 1.0	6.7 ± 1.1
SDNN	134 ± 46	132 ± 44	108 ± 22	110 ± 35	150 ± 46	148 ± 57
SDANN	113 ± 42	112 ± 43	94 ± 22	95 ± 32	127 ± 37	127 ± 52
pNN50	16 ± 15	17 ± 17	11 ± 6	12 ± 9	23 ± 15	19 ± 12
rMSSD	53 ± 34	54 ± 36	41 ± 15	46 ± 25	72 ± 37	62 ± 36
QoL, health perception [†]	2.85 ± 0.67	3.00 ± 0.73	2.33 ± 0.87	2.78 ± 0.83	2.40 ± 0.84	3.10 ± 0.57

Note. BMI = body mass index; DM = diabetes mellitus; HDL = high-density lipoprotein; high frequency ($\ln \text{ms}^2$) = parasympathetic modulation; LDL = low-density lipoprotein; low frequency ($\ln \text{ms}^2$) = sympathetic modulation; pNN50 = % of adjacent R-R intervals with 50 ms difference; QoL = quality of life measured with the Diabetes Quality of Life Measure for Youth; rMSSD = square root of the mean of the sum of squares of ms differences between adjacent R-R intervals; SDANN = standard deviation (ms) of the means of R-R intervals for each 5-min epoch; SDNN = standard deviation (ms) of all R-R intervals; total frequency ($\ln \text{ms}^2$) = sympathetic and parasympathetic modulation; VO₂ peak = peak oxygen consumption during exercise, an indicator of cardiorespiratory fitness.

[†] p .01 for time main effect.

* p < .05 for group main effect.

** p .001 for group main effect.

Table 2

Demographics and Baseline Measures of Participants.

Characteristic or Measure	Total (<i>N</i> = 39)	Type 1 DM (<i>n</i> = 20)	Type 2 DM (<i>n</i> = 9)	Obese (<i>n</i> = 10)
Gender, female	23	9	8	6
Ethnicity				
Hispanic	23	9	7	7
Non-Hispanic	16	11	2	3
Age (years)	14.4 ± 1.6	14.2 ± 1.5	14.7 ± 1.8	14.6 ± 1.6
Height (cm)		164.6 ± 7.7	162.8 ± 5.8	166.1 ± 9.0
Weight (kg)		62.6 ± 10.7 ^a	100.6 ± 22.7 ^b	102.1 ± 24.9 ^b
Waist circumference (cm)		80.9 ± 11.7 ^a	124.0 ± 14.4 ^b	114.5 ± 17.2 ^b
BMI percentile		73.3 ± 27.4 ^a	98.5 ± 1.7 ^b	98.8 ± 1.1 ^b
BMI <i>z</i> -score		0.86 ± 1.0 ^a	2.4 ± 0.4 ^b	2.4 ± 0.3 ^b
Physical Activity Recall (MVPA min/day)	11.0 ± 12.4	8.9 ± 10.0	9.1 ± 7.8	17.1 ± 18.2
Duration of DM (years)		5.8 ± 2.9 ^a	1.6 ± 1.4 ^b	
HbA _{1c} (%)		9.2 ± 1.9 ^a	8.4 ± 1.8 ^a	5.4 ± 0.3 ^b
VO ₂ peak (ml/kg/min)		33.0 ± 7.6 ^a	20.2 ± 3.5 ^b	23.2 ± 4.0 ^b

Note. Data are presented as mean ± *SD* or frequency, as appropriate. BMI = body mass index; DM = diabetes mellitus; MVPA = moderate-to-vigorous physical activity; SD = standard deviation; VO₂ peak (ml/kg/min) = peak oxygen consumption during exercise, an indicator of cardiorespiratory fitness.

^{a,b} Data marked with superscript *a* are significantly different than data in the same row marked with superscript *b*, *p* < .01.

Table 3

Accelerometry and Moderate-to-Vigorous Physical Activity (MVPA) Data by Group.

Measure	Total	Type 1 DM	Type 2 DM	Obese
Mean accelerometer wear time (hr/day)	12.5 ± 2.7	13.0 ± 2.8 ^a	10.4 ± 2.7 ^b	13.6 ± 1.3 ^a
Days of accelerometer data	73.4 ± 27.2	66.5 ± 6.0	83.7 ± 9.0	78.1 ± 8.5
Frequency ^c 10 min/day MVPA	90.1 ± 9.6	88.2 ± 11.2	92.6 ± 7.8	91.8 ± 7.4
Frequency 30 min/day MVPA	70.4 ± 19.8	69.1 ± 22.0	66.3 ± 17.6	76.8 ± 17.0
Frequency 60 min/day MVPA	38.2 ± 25.6	42.0 ± 24.7	20.6 ± 20.7	46.3 ± 26.1
Daily MVPA (min)	42.5 ± 22.1	42.4 ± 19.7	30.4 ± 13.6	53.4 ± 28.2
MVPA intensity (METS)	04.1 ± 0.3	04.1 ± 0.4	04.0 ± 0.2	04.0 ± 0.3

Note. Data are presented as mean ± SD. METS = metabolic equivalents; DM = diabetes mellitus; SD = standard deviation.

^{a,b} Data marked with superscript *a* differ significantly from data in the same row marked with superscript *b*, *p* < .05.

^c Frequency indicates the percentage of days in which adolescents performed a minimum amount of cumulative MVPA.

Correlations Between Adherence to the Moderate-to-Vigorous Physical Activity (MVPA) Intervention and Glycemic Control (HbA_{1c}) and Fitness (VO₂ peak) for Subjects With Diabetes Mellitus (DM).

Table 4

Measure of MVPA Adherence	Change HbA _{1c}			Change VO ₂ Peak		
	Total Sample	Type 1 DM	Type 2 DM	Total Sample	Type 1 DM	Type 2 DM
Frequency MVPA 10 min/day	-.220	-.156	-.363	.314	.245	.635 [†]
Frequency MVPA 30 min/day	-.485 ^{**}	-.521 [*]	-.434	.226	.182	.365
Frequency MVPA 60 min/day	-.304	-.469 ^{**}	-.168	.259	.285	.344
Mean daily MVPA	-.392 [*]	-.526 [*]	-.260	.308	.394 [†]	.241
MVPA intensity	-.262	-.329	-.180	-.225	-.338	.059

[†] $p < .10$.

^{*} $p < .05$.

^{**} $p < .01$.