Prevention of Type 2 Diabetes Among Youth: A Systematic Review, Implications for the School Nurse

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Abstract

Childhood obesity and the early development of type 2 diabetes (T2 DM) place students at risk for chronic health problems. The school nurse is uniquely situated to promote school health initiatives that influence health behavior. The purpose of this review was to determine effective nonpharmacological interventions for prevention of T2 DM in youth. Researchers from 35 reports modified T2 DM risk factors. These nonpharmacological interventions often include increasing daily activity, decreasing caloric intake, and increasing muscle mass. Some researchers also included psychological and social support interventions intended to strengthen initiating and/or maintaining health behavior. Characteristics of effective nonpharmacological T2 DM prevention interventions are discussed. Findings from this review are a useful guide for the implementation of T2 DM prevention strategies in the school setting. Few school-based studies included high school students; therefore, further research is needed among older adolescents on the efficacy of nonpharmacological interventions in the high school.

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Introduction

The school nurse is no stranger to the treatment of type 1 diabetes in youth. Type 1 diabetes is an autoimmune disease that destroys pancreatic β cell function creating an absolute loss of insulin. Once rare in youth, type 2 diabetes (T2 DM) is observed as a gradual increase in blood glucose caused by a relative insulin deficit. In T2 DM, the insulin resistant body requires more insulin to maintain normal glycemia. The pancreatic β cells increase insulin production to maintain this balance. Increased circulating insulin contributes to weight gain. Eventually, the pancreatic β cell function declines resulting in a relative insulin deficit as evidenced by hyperglycemia and T2 DM. The incidence of both types of diabetes is predicted to grow exponentially among youth (D'Adamo & Caprio, 2011). The scope and cause of this increase is multifaceted. Currently, no prevention strategy is available for type 1 diabetes; however, T2 DM is preventable. The school nurse can influence the future well-being of students at risk for or living with T2 DM.

The SEARCH study (Dabelea et al., 2007) identified minorities aged 15–19 as the largest group of youth in the United States afflicted by T2 DM. The incidence (per 100,000 person-years) was as follows: Native Americans (49.4), Asian/Pacific Islanders (22.7), African Americans (19.4), and Hispanics (17). In contrast, the incidence in non-Hispanic Whites was 5.6. In addition to ethnicity, visceral obesity and its contribution to insulin resistance placed students at risk for T2 DM. Sinha et al. (2002) reported that independent of ethnicity, obese children (25%) and obese adolescents (21%) were found to have impaired glucose tolerance, a precursor to T2 DM. Among youth, ectopic visceral fat is most predictive of insulin resistance, one of the two major pathologies associated with T2 DM. Visceral fat can be accurately measured with computed tomography (CT) imaging. However, this is not practical on a large scale. Bray and Bouchard (2014) discuss the correlation of anthropometric measures (trunk skin folds, waist circumference, and body mass index [BMI]) and their correlation with the CT measures of adiposity in children and adolescents. Identifying obese children at risk for T2 DM is important in order to interrupt progression of the disease. Once identified, school-aged youth need effective nonpharmacological interventions to prevent symptoms of T2 DM.

In order to determine effective interventions, a systematic review was used to identify and evaluate published reports of nonpharmacological interventions to prevent T2 DM symptoms among youth. The Agency for Health care Research and Quality has two reports, one on childhood obesity prevention programs (Wang et al., 2013) and the second on obesity treatment (Whitlock, O'Connor, Williams, Beil, & Lutz 2010). Both provide a broader context for this issue beneficial to the school nurse. This review includes both studies for prevention of obesity and studies with youth already identified as obese. Thirty-five reports are included in this review. These reports are grouped based on the intervention's location (school, family, community, and clinic). Once grouped, it became evident that characteristics of the youth enrolled in the studies varied based on the research study location. Youth (aged 9–13) were more likely to be enrolled in a school, family, or community intervention. Older students (aged 12–18) were more likely to be enrolled in a clinic-based intervention.

Two studies were identified with high school-aged students. One of these was with students having intellectual disabilities. With the lack of school-based interventions for high school-aged youth, the school nurse of older youth needs to question the applicability of school-based findings to the high school setting. Older adolescents were more likely to be enrolled in clinic-based interventions. The school nurse should consider the role of clinic-based interventions held in the school setting for these students.

Method

PubMed was systematically searched (Tables 1 and 2) for diabetes and obesity prevention studies that did not include pharmaceutical intervention or youth already diagnosed with diabetes. The search results were compiled, analyzed, and compared. The search strategy has limitations, as it does not include articles that may have been published but did not have medical subject headings (MeSH) assigned. Future studies of this subject may benefit from searches using the term "metabolic diseases (X)" in addition to or in place of metabolic syndrome. Strengths and weaknesses of each study were identified in order to identify interventions likely to be effective in preventing T2 DM among children and adolescents. Articles reviewed in this study met the following criteria: age less than 20 and not diagnosed with diabetes, interventions targeted lifestyle/behavioral change, English language, and published within the past 5 years. On March 7, 2014, the search was updated extending the study to include 6 years of research reports. Several English language reports of international studies were included due to the potential of these studies to represent different ethnic groups found within the United States (Damsgaard et al., 2013; Demol et al., 2008; Garanty-Bogacka et al., 2011; Pedrosa et al., 2010a, 2010b; Reinehr, Kleber, & Toschke, 2009; Szamosi et al., 2008; Wallén, Müllersdorf, Christensson, & Marcus, 2013).

Results

The 35 articles included in this systematic review by intervention location were school based ($n = 9$), family based ($n = 4$), community based ($n = 7$), or clinic based ($n = 15$). In several cases, researchers presented results in multiple reports derived from the same large studies (Tables 3–6). Study interventions resulted in health improvements among children and adolescents defined by statistically significant changes in metabolic, dietary, and/or physical activity outcome measurements compared to baseline (Table 7). Researchers commonly implemented interventions employing physical activity, nutritional education, and behavioral therapy.

School-Based Interventions

The nine school-based interventions (Table 3) occurred during the school day or in after-school programs and included students from 4th to 12th grade collectively (DeBar et al., 2011; Grey et al., 2009; Hogg et al., 2012; Jago et al., 2011; Jefferson et al., 2011; Schneider et al., 2013; Staiano, Abraham, & Calvert, 2013; The HEALTHY Study Group, 2010; Wallén et al., 2013). Youth in these grades are usually 9–18 years old. DeBar et al. (2011), Jago et al. (2011), Schneider et al. (2013), and The HEALTHY Study Group (2010) all reported results from the larger school-based study, The HEALTHY Study. The HEALTHY Study Group reported nonsignificant health improvements from a very large sample ($n = 4{,}603$) relative to a control after a 2-year intervention that included nutrition education, physical activity, behavior therapy, communication, and marketing components. Schneider et al. examined the role of the communication campaign on health behavior and concluded that schools with more students reporting awareness of the communication campaign also adopted more of the healthy behaviors. They recommend encouraging students to generate their own media to improve awareness. Jago et al. (2011) performed a secondary analysis of data obtained from The HEALTHY Study and concluded that there were no significant differences in health improvements between intervention and control schools. However, those students with higher levels of involvement in public commitment activities were positively correlated with improved metabolic measurements within The HEALTHY Study. In a study including coping skills training (CST), Grey et al. (2009) and Jefferson et al. (2011) in two separate reports ($n = 198$, $n = 98$) concluded that CST was effectively delivered via telephone for improving and maintaining metabolic health measurements following nutritional education and physical activity intervention. Two innovative studies incorporated physical activity for students. The first, Staiano, Abraham, and Calvert (2013), employed an exergame for overweight

Table 1. Search Methodology December 15, 2012.

Numbers	Search Terms	Found	Included	Excluded
1.	"Type-2 Diabetes" • [AND] intervention • [AND] adolescen* • [NOT] "type 1 diabetes"	42	1. (Davis et al., 2009) 2. (Davis et al., 2010) 3. (Davis et al., 2011) 4. (Davis et al., 2012) 5. (Demol et al., 2008) 6. (Garanty-Bogacka et al., 2011) 7. (Jefferson et al., 2011) 8. (Ventura et al., 2009)	Total: 34 • Not assessing results of an intervention: 9 • Not directly related to diabetes: 3 • Already have diabetes: 2 • Study protocol: 7 • Preventative ideas not implemented in an intervention: 5 • International: 5 • Surgical/pharmaceutical: 2 • Review article: 1
2.	"Type-2 Diabetes" • [AND] intervention • [AND] youth • [NOT] "type 1 diabetes"	24	1. (Grey et al., 2009)	Total: 23 • Previously selected: 7 • Not assessing results of an intervention: 5 • Already have diabetes: 2 • Study protocol: 5 • Preventative ideas not implemented in an intervention: 3 • International: 1
3.	"Type-2 Diabetes" • [AND] intervention • [AND] child* • [NOT] "type 1 diabetes"	60	1. (Raman et al., 2010) 2. (Sharma & Fleming, 2012)	Total: 58 • Previously selected: 8 • Not assessing results of an intervention: 10 • Not directly related to diabetes: 4 • Already have diabetes: 6 • Study protocol: 12 • Preventative ideas not implemented in an intervention: 8 • International: 10
4.	"Type-2 Diabetes" • [AND] prevention • [AND] adolescen* • [NOT] "type 1 diabetes"	52	None	Total: 52 • Previously selected: 1 • Not assessing results of an intervention: 19 • Already have diabetes: 3 • Study protocol: 5 • Preventative ideas not implemented in an intervention: 9 • International: 9 • Surgical/pharmaceutical: 3 • Not youth: 3
5.	"Type-2 Diabetes" • [AND] prevention • [AND] youth • [NOT] "type 1 diabetes"	14	None	Total: 14 • Not assessing results of an intervention: 5 • Already have diabetes: 2 • Study protocol: 4 • Preventative ideas not implemented in an intervention: 2 • International: 1
6.	"Type-2 Diabetes" • [AND] prevention • [AND] child* • [NOT] "type 1 diabetes"	89	Excluded	
7.	"Type-2 Diabetes" • [AND] self-efficacy • [AND] adolescen* • [NOT] "type 1 diabetes"	2	None	Total: 2 • Previously selected: 1 • Already have diabetes: 1
8.	"Type-2 Diabetes" • [AND] self-efficacy • [AND] youth • [NOT] "type 1 diabetes"	3	None	Total: 3 • Previously selected: 1 • Not assessing results of an intervention: 1 • Preventative ideas not implemented in an intervention: 1

Table 1. (continued)

Numbers	Search Terms	Found	Included	Excluded
9.	"Type-2 Diabetes" • [AND] self-efficacy • [AND] child* • [NOT] "type 1 diabetes"	3	1. (Smith, Annesi, Walsh, Lennon, & Bell, 2010)	Total: 2 • Previously selected: 1 • Study protocol: 1
10.	"Metabolic Syndrome" • [AND] intervention • [AND] adolescen* • [NOT] "type 1 diabetes"	38	1. (Coppen, Risser, and Vash (2008) 2. (de Mello et al., 2011) 3. (Dorgan et al., 2011)	Total: 35 • Previously selected: 1 • Not assessing results of an intervention: 12 • Not directly related to metabolic syndrome: 5 • Preventative ideas not implemented in an intervention: 6 • International: 8 • Surgical/pharmaceutical: 3
11.	"Metabolic Syndrome" • [AND] intervention • [AND] youth • [NOT] "type 1 diabetes"	8	None	Total: 8 • Previously selected: 1 • Not assessing results of an intervention: 3 • Preventative ideas not implemented in an intervention: 3 • International: 1
12.	"Metabolic Syndrome" • [AND] intervention • [AND] child* • [NOT] "type 1 diabetes"	53	1. (Pedrosa et al., 2010a) 2. (Pedrosa et al., 2010b) 3. (Reinehr, Kleber, & Toschke, 2009)	Total: 50 • Previously selected: 4 • Not assessing results of an intervention: 14 • Not directly related to metabolic syndrome: 9 • Preventative ideas not implemented in an intervention: 12 • International: 9 • Surgical/pharmaceutical: 1 • Not youth: 1
13.	"Metabolic Syndrome" • [AND] prevention • [AND] adolescen* • [NOT] "type 1 diabetes"	46	None	Total: 46 • Not assessing results of an intervention: 15 • Not directly related to metabolic syndrome: 2 • Preventative ideas not implemented in an intervention: 7 • International: 21 • Surgical/pharmaceutical: 1
14.	"Metabolic Syndrome" • [AND] prevention • [AND] youth • [NOT] "type 1 diabetes"	5	None	Total: 5 • Not assessing results of an intervention: 3 • Preventative ideas not implemented in an intervention: 2
15.	"Metabolic Syndrome" • [AND] prevention • [AND] child* • [NOT] "type 1 diabetes"	63	Excluded	
16.	"Metabolic Syndrome" • [AND] self-efficacy • [AND] adolescen* • [NOT] "type 1 diabetes"	0	None	None
17.	"Metabolic Syndrome" • [AND] self-efficacy • [AND] youth • [NOT] "type 1 diabetes"	0	None	None
18.	"Metabolic Syndrome" • [AND] self-efficacy • [AND] child* • [NOT] "type 1 diabetes"	0	None	None

Table 1. (continued)

Numbers	Search Terms	Found	Included	Excluded
Additional articles from PubMed MeSH search: "Diabetes Mellitus, Type 2," prevention and control, [Majr]				
1. (Benavides & Caballero, 2009)				
2. (Burnet et al., 2011)				
3. (DeBar et al., 2011)				
4. (Hogg et al., 2012)				
5. (Jago et al., 2011)				
6. (Shaibi et al., 2012)				
7. (The HEALTHY Study Group, 2010)				
8. (Wickham et al., 2009)				
Additional articles from CINAHL advanced search: "Adolescen*, Type-2 Diabetes, Preven*"				
1. (Raynor et al., 2012)				
2. (Szamosi et al., 2008)				

Note. PubMed advanced search; filters: publication date—past 5 years; language—English; age—birth to 18 years; species—Human.

Table 2. Search Methodology Update March 7, 2014.

Numbers	Search Terms	Found	Included	Excluded
1.	PubMed • "Type-2 Diabetes" • "Metabolic Syndrome" • [AND] adolescen* • [AND] youth • [AND] child • [AND] intervention • [AND] prevention • [AND] self-efficacy • [NOT] "type-1 diabetes"	83	Total: 5 1. (Damsgaard et al., 2013) 2. (Patrick et al., 2013) 3. (Schneider et al., 2013) 4. (Wallén, Müllersdorf, Christensson, & Marcus, 2013) 5. (Mirza et al., 2013)	Total: 78 • Not assessing results of an intervention: 25 • Not youth: 12 • Not directly related to diabetes: 6 • Preexisting diabetes: 1 • Study protocol: 4 • Surgical: 3 • Pharmaceutical: 18 • Review: 9
2.	PubMed Major MeSH	17	Total: 1 1. (Wofford, Froeber, Clinton, & Ruchman, 2013)	Total: 16 • Previously selected: 2 • Already excluded: 11 • Not assessing results of an intervention: 1 • Not youth: 1 • Pharmaceutical: 1
3.	PubMed not intervention	35	Total: 1 1. (Staiano, Abraham, & Calvert, 2013)	Total: 34 • Previously selected: 4 • Already excluded: 25 • Not assessing results of an intervention: 3 • Review: 1 • Surgical: 1
4.	CINAHL DM	16	Total: 0	Total: 16 • Previously selected: 3 • Already excluded: 9 • Not assessing results of an intervention: 4
5.	CINAHL Major MeSH	8	Total: 0	Total 8 • Previously selected: 1 • Already excluded: 7

Note. PubMed advanced search; filters: publication date—January 2013 to March 7, 2014; language—English; age—birth to 18 years.

and obese African American adolescents using the Nintendo Wii Active. They created three conditions: competitive, cooperative, and control. Students participated during lunch and/or after school. The cooperative group lost significantly more weight. The second, Hogg et al. (2012), reported interventions using dance and lifestyle classes culturally sensitive to a Hispanic population resulted in increased attendance and significant improvements in metabolic measurements. Both of these studies provided culturally sensitive interventions. In Sweden, Wallén, Müllersdorf, Christensson, and Marcus (2013) examined the effect of a multifactorial school-wide healthy initiative on students with intellectual

Table 3. Characteristics of School-Based Interventions.

Study	Article	Sample Size/Age	Duration/Description	Results
The HEALTHY STUDY	The HEALTHY Study Group (2010)	$n = 4{,}603$ (6th grade)	2 Years; nutritional education, physical activity (PA), behavior therapy, and communication/marketing	Decreased BMI z score and mean insulin level (No other markers were significantly different than control schools)
	Jago et al. (2011)	$n = 4{,}603$ (6th grade)	2 Years; nutritional education, PA, behavior therapy, and communication/marketing	No significant differences in metabolic syndrome, fitness level, or PA between control and intervention group
	DeBar et al. (2011)	$n = 4{,}603$ (6th grade)	2 Years; nutritional education, PA, behavior therapy, and communication/marketing	Positive correlation between involvement in public commitment activities and likelihood of decreased metabolic risk
	Schneider et al. (2013)	$n = 2{,}307$ (6th grade)	3 Years; process evaluation and descriptive study of the communication campaign and health behavior change	Implementation was variable; however, correlation and regression analysis indicated that increased exposure to communication campaign materials stimulated greater health behavior change
Study involving coping skills training	Grey et al. (2009)	$n = 198$ (7th grade)	16 Weeks; (C) nutritional education and PA (I) nutritional education and PA with additional coping skills training via telephone (9-month follow-up with weekly phone calls to participants of both groups)	(C): Improvements in BMI, body fat, waist circumference (maintained after 12 months), HOMA, fasting insulin, and 2-hr insulin levels, triglycerides, increased HDL, LDL, and cholesterol (I): Improved 2-hr glucose levels and greater increase in HDL levels
	Jefferson et al. (2011)	$n = 98$ (7th grade)	9 Months; health coaching and coping skills training via weekly telephone sessions as ongoing support	Improved 2-hr glucose and higher HDL levels relative to the control group
Unaffiliated	Hogg et al. (2012)	$n = 64$ (4th–5th grade)	16 Weeks; after-school PA via freestyle dance and nutritional education via lifestyle program	Improved RHR, BMI, percentage body fat, total cholesterol, glucose, LDL, non-HDL, total cholesterol:HDL ratio, and HOMA-IR
	Wallén, Müllersdorf, Christensson, and Marcus (2013)	$n = 11$ (Aged 16–18; Down syndrome and other intellectual disabilities)	2-Year study. School-wide program (STOPP) no sweet drinks or treats or fat foods during school day. Daily PA 60 min (3 days/week) 20 min (2 days/week). School provided healthy meals including breakfast, lunch, after-school snack. Lunch was served on plate model plates, monthly newsletter, 3- to 4-day school health camp yearly	Decrease in cardiometabolic risk factors including decrease in central obesity and increase in cardiovascular fitness
	Staiano, Abraham, and Calvert (2013)	$n = 54$ (9th–12th grade; obese African American)	20 Weeks; 30–60 min playing an exergame (competitive, cooperative, and control) daily during lunch or after school	Cooperative exergame group lost significantly more weight than control and improved increased self-efficacy. Measured weight change, peer support, self-efficacy, and self-esteem

Note. BMI = body mass index; HOMA = homeostasis model assessment; HOMA-IR = homeostasis model assessment of insulin resistance; RHR = resting heart rate.

Table 4. Characteristics of Family-Based Interventions.

Study	Article	Sample Size/Age	Duration/Description	Results
Reach-Out	Burnet et al. (2011)	$n = 62$ (Aged 9–12; African American)	14 Weeks; weekly nutritional education and physical activity (monthly meeting for remainder of 1 year)	Decreased BMI *z* scores (maintained after 1 year); Increased walking with correlated increase in HDL after 14 weeks (not maintained after 1 year)
DISC06	Dorgan et al. (2011)	$n = 230$ (Aged 8–10)	3-Year dietary intervention follow-up	Lower fat and cholesterol intake, higher fiber intake; improved systolic blood pressure, fasting glucose, and VLDL
Diogenes	Damsgaard et al. (2013)	$n = 253$ (Aged 5–18) Children of obese parents pan European	6 Months; randomized into five groups. Nutrition education for families with six follow-up visits. Emphasis on low glycemic intake and high-protein diets	Increased protein intake improved CVD risk markers. Low GI diets had no consistent effect on CVD risk markers
Unaffiliated	Raynor et al. (2012)	$n = 182$ (Aged 4–9)	6 Months; four groups [DECREASE]: reduced snacks and sugar-sweetened beverages, [INCREASE]: increased intake of healthy foods, [TRADITIONAL]: decreased sugar-sweetened beverages and increase physical activity, and [SUBSTITUTES]: increased low-fat milk intake and decreased sedentary activity (12-month follow-up)	Improved BMI *z* and diet similar within all groups

Note. BMI = body mass index; CVD = cardiovascular disease; GI = glycemic index.

disabilities. These students improved measures of adiposity and cardiovascular health when exposed to a controlled healthy school environment. In summary, the school-based interventions included five intervention strategies: a large controlled and comprehensive interventional study (The HEALTHY Study), the telephone-based CST study, a report on the response of those with intellectual disabilities to a multifactorial school intervention, an exergame intervention for African American adolescents, and an after-school dance intervention for Hispanic students.

Family-Based Interventions

Included in this review are four reports (Table 4) of family-based intervention provided to youth 4–18 years of age, along with at least one adult family member (Burnet et al., 2011; Damsgaard et al., 2013; Dorgan et al., 2011; Raynor et al., 2012).Burnet et al. (2011) reported that African American children and parents decreased and maintained BMI *z* scores after a weekly nutritional education and physical activity intervention followed by a year of monthly follow-up meetings for ongoing support. Damsgaard et al. (2013) designed a dietary intervention for families with one or more overweight parent in eight European countries. Youth aged 5–18 who increased protein intake improved cardiovascular markers including waist circumference. Dorgan et al. (2011) demonstrated the effectiveness of nutritional education for improving dietary and metabolic measurements over a 3-year period. Raynor et al. (2012) reported on a family-based intervention in a clinic setting that decreased and maintained BMI *z* scores, as well as improved dietary health measurements 6 months after the study intervention. In general, the participants in family-based interventions were younger than participants in the clinic-based interventions and all family-based interventions had a nutritional focus.

Community-Based Interventions

Seven community-based studies (Table 5) involved group participation and encouraged participants to work together to overcome challenges (Benavides & Caballero, 2009; Pedrosa et al., 2010a, 2010b; Raman et al., 2010; Shaibi et al., 2012; Sharma & Fleming, 2012; Wofford, Froeber, Clinton, & Ruchman, 2013). Participants included in community-based studies were between 7 and 16 years old. Benavides and Caballero (2009) in one small study ($n = 14$) reported short-term improvements in metabolic measurements from group yoga sessions alone. In Portugal, Pedrosa et al. (2010a, 2010b) reported greater improvements in metabolic measurements from group treatment employing nutritional education classes versus individual treatment at 3-, 6-, and 12-month follow-ups. Sharma and Fleming (2012) and Raman et al. (2010) in two separate articles reported results from the Taking Action Together (TAT) study of African American children. Raman et al. reported increased insulin sensitivity in African American boys after a 2-week summer day camp including both physical activity and nutritional education components. In contrast, African American girls did not show significant improvements in insulin sensitivity following the TAT study (Raman et al., 2010). Sharma and Fleming in another report from the TAT study stated that African American children demonstrated improved dietary health measurements. Following a 12-week program of

Table 5. Characteristics of Community-Based Interventions.

Study	Article	Sample Size/Age	Duration/Description	Results
Study involving lifestyle intervention program	Pedrosa et al. (2010a)	$n = 61$ (Aged 7–9)	Four intervention sessions; group treatment (GT, $n = 19$) or individual treatment (IT, $n = 42$). Nutritional education and suggested physical activity. Follow-up measurements at 3 months, 6 months, and 1 year	GT and IT: Improved BMI *z*, waist circumference to height ratio (more significant in GT); decreased prevalence of metabolic syndrome GT: Improved HDL *Slight decrease in improvements at 1 year
	Pedrosa et al. (2010b)	$n = 61$ (Aged 7–9)	Four intervention sessions; GT, $n = 19$ or IT, $n = 42$. Nutritional education and suggested physical activity. Follow-up measurements at 3 months, 6 months, and 1 year	GT and IT: Improved BMI *z*, waist circumference to height ratio, and diastolic blood pressure (more significant in GT); decreased prevalence of metabolic syndrome GT: Improved HDL, adiponectin, and ghrelin levels, leptin *Slight decrease in improvements at 1 year
Taking Action Together (TAT)	Raman et al. (2010)	$n = 109$ (Aged 9–11; African American)	2 Weeks; daily nutritional education, physical activity, and self-esteem instruction (12 months of weekly follow-up sessions or monthly newsletter)	Boys: Improvements in HOMA-IR and fasting insulin Girls: no significant differences between groups
	Sharma and Fleming (2012)	$n = 89$ (Aged 9–10; African American)	1 Year; nutritional education	Boys: reduced intake of total energy, total fat, discretionary fat, and sweetened beverages Girls: increased intake of whole grains
Every Little Step Counts–Diabetes Prevention Program (ELSC-DPP)	Shaibi et al. (2012)	$n = 15$ (Aged 14–16; Hispanic)	12 Week; of lifestyle education (once a week) and physical activity sessions (3 times a week)	Improvements in BMI percentile, BMI *z* score, waist circumference, 2-hr glucose, 2-hr insulin, AUC (for both glucose and insulin), cardiorespiratory fitness, and insulin sensitivity; increased physical activity and decreased servings of fat per day reported
Unaffiliated	Benavides and Caballero (2009)	$n = 14$ (Aged 8–15)	12 Weeks, 1.25-hr yoga sessions 3 times a week	Improved weight, BMI, total cholesterol, cardiac-specific C-reactive protein, HDL, self-esteem, depression, and anxiety
	Wofford, Froeber, Clinton, and Ruchman (2013)	$n = 46$ (Aged 6–14; African American)	12 Weeks; CASTLES after school model that includes nutrition information and structured physical activity	Increased health knowledge, decreased sugar-sweetened beverages, decreased screen time, and increased physical activity

Note. BMI = body mass index; HOMA-IR = homeostasis model assessment of insulin resistance; AUC = area under the curve.

Table 6. Characteristics of Clinic-Based Interventions.

Study	Article	Sample Size/Age	Duration/Description	Results
Study involving nutritional education and strength training	Davis et al. (2009)	$n = 54$ (Age 14–18; Hispanic)	16 Weeks; three groups: (1) weekly nutrition education, (2) weekly nutrition + biweekly strength training, and (3) control	(1) and (2): Improved glucose IAUC
	Ventura et al. (2009)	$n = 54$ (Age 14–18; Hispanic)	16 Weeks; three groups: (1) weekly nutrition education, (2) weekly nutrition + biweekly strength training, and (3) control	Decreased added sugar intake (correlated with decreased insulin secretion); increased dietary fiber intake (correlated with improved BMI and visceral adipose tissue) *No significant differences between control and intervention
	Davis et al. (2010)	$n = 114$ (Age 12–16; Hispanic)	16 Weeks; four groups: (1) strength training, (2) nutritional education, (3) nutritional education and strength training, and (4) nutritional education and aerobic and strength training	(1): Improved insulin sensitivity by 45% (2, 3, and 4): improved glucose control (4): significantly reduced adiposity measurements
	Davis et al. (2011)	$n = 38$ (Age 14–18; Hispanic girls)	16 Weeks; two groups: (1) circuit training and (2) circuit training and motivational interviewing (MI)	(1 and 2): Improved strength, VO_{2max}, waist circumference, SAT, VAT, fasting insulin, and HOMA-IR; *No significant differences between CT and CT + MI
	Davis et al. (2012)	$n = 53$ (Mean age of 15.4; Hispanic and African American)	4 Months; nutritional education and physical activity via strength training (8 months of monthly follow-up sessions or monthly newsletters)	Both follow-up groups: Improved HDL, fasting insulin, AIR, and SI
Pace-Internet for Diabetes Prevention Intervention PACEi-DP	Patrick et al. (2013)	$n = 101$ (Age 12–16) 74% Hispanic	12 Months; RCT with four groups usual care (UC), website only (W), website with monthly meetings (WG), website with text (WSMS). Website focused on behavioral intervention for weight loss	No treatment effects on BMI, adiposity, PA, or diet at 12 months. The website group decreased sedentary behavior more than usual care
Obeldicks	Reinehr, Kleber, and Toschke (2009)	$n = 288$ (Age 10–16)	1 Year; three phases: (1) 3 months; bimonthly behavioral therapy and nutrition education and weekly physical activity, (2) 6 months; weekly individual psychological therapy and physical activity, and (3) weekly physical activity	Improved SDS-BMI, waist circumference, blood pressure, LDL cholesterol, 2-hr glucose, and prevalence of metabolic syndrome

(continued)

Table 6. (continued)

Study	Article	Sample Size/Age	Duration/Description	Results
Unaffiliated	Coppen, Risser, and Vash (2008)	n = 135 (Age 12–19)	10 Weeks; nutritional education physical activity	Improved weight, blood pressure, triglycerides, waist circumference, total cholesterol, and BMI
	De Mello et al. (2011)	n = 30 (Age 15–19)	1 Year; two groups: (1) nutritional education and circuit training and (2) nutritional education and resistance training; *Psychological support once a week and clinical support once a month in both groups	(1 and 2): Improved metabolic risks (greater improvements in AT + RT group) *12/15 Participants in the AT group resolved their diagnosis of the metabolic syndrome, while 15/15 participants in the AT + RT group did
	Demol et al. (2008)	n = 55 (Age 12–18)	12 Weeks; three groups: (1) low-carb, low-fat, protein-rich diet, (2) low-carb, high-fat diet, and (3) high-carb, low-fat diet. Weekly sessions with dietitian and psychologist (follow-up after 9 months)	(1, 2, and 3): Improved BMI, BMI-SDS, and body fat (1 and 2): improved insulin and HOMA level *Improvements in BMI and BMI-SDS were maintained after 9-month follow-up, body fat was not
	Garanty-Bogacka et al. (2011)	n = 50 (Age 8–18)	6 Months; physical activity, nutrition education, and behavior therapy	Improved weight, SDS-BMI, waist circumference, percentage body fat, glucose and insulin concentration, HOMA-IR, HbA1c, SBP and DBP, CRP, WBC, and FB
	Mirza et al. (2013)	n = 113 (Age 7–15) obese Hispanic	2 Year (3 months of treatment and 24 months of follow-up); randomized into two groups: low glycemic or low-fat diets	BMI z, BP, waist circumferences improved over the 2 years. However, one diet was not better than the other and the initial improvements declined with time
	Smith, Annesi, Walsh, Lennon, and Bell (2010)	n = 23 (Age 10–14)	12 Weeks; biweekly physical activity, four nutrition consultations, and two food demonstrations	Improved BMI and total cholesterol level; increased voluntary physical activity per week

Note. CT = computed tomography; BMI = body mass index; IAUC = incremental area under the curve; VAT = visceral adipose tissue; SAT = subcutaneous adipose tissue; HOMA-IR = homeostasis model assessment of insulin resistance; AIR = acute insulin response; SDS = standard deviation score; CRP = C-reactive protein; FB = fasting blood glucose; SBP = systolic blood pressure; DBP = diastolic blood pressure; WBC = white blood cell; BP = blood pressure; RCT = randomized control trial; SI = insulin sensitivity; AT = aerobic trained; RT = resistance trained.

Table 7. Study Outcome Measures.

Outcome	Indicator	Measure
Metabolic	Adiposity	Percentage body fat
		Waist circumference
		Waist circumference to height ratio
		Weight
		BMI
		BMI z score
		BMI-SDS
		Visceral adipose tissue (VAT)
		Subcutaneous adipose tissue (SAT)
	Glucose/insulin	Insulin sensitivity
		Fasting insulin
		2-hr insulin
		HOMA-IR
		HOMA
		SI
		AUC (insulin)
		AIR
		Ghrelin
		Leptin
		Oral glucose insulin sensitivity (OGIS)
		Fasting glucose (FB)
		2-hr glucose (PPG)
		AUC (glucose)
		Adiponectin
		HbA1c
		Glucose IAUC
	Lipid profile	Triglycerides
		Total cholesterol
		HDL
		LDL
		VLDL
		Total cholesterol:HDL ratio
	Vascular	RHR
		Systolic blood pressure
		Diastolic blood pressure
		Cardiac-specific C-reactive protein (CRP)
		CRP
		WBC
Dietary	Fat intake	
	Cholesterol intake	
	Fiber intake	
	Energy intake	
	Sugar-sweetened beverages	
	Whole grains	
	Added sugar intake	
Physical activity	Fitness level	
	Physical activity	
	Walking	
	Cardiorespiratory fitness	
	Strength	
	VO_{2max}	

Note. BMI = body mass index; SDS = standard deviation score; HOMA-IR = homeostasis model assessment of insulin resistance; IAUC = incremental area under the curve; AUC = area under the curve; WBC = white blood cell; RHR = resting heart rate; AIR = acute insulin response; SI = insulin sensitivity.

lifestyle/nutrition education and physical activity for Hispanic adolescents, Shaibi et al. (2012) demonstrated significant short-term improvements in metabolic, dietary, and physical activity measurements. Wofford, Froeber, Clinton, and Ruchman (2013) worked with African American youth aged 4–16 in an after-school program with daily activity, healthy snack, and lessons on health/nutrition for 12 weeks. Participation reduced hours of screen time and decreased consumption of sugar-sweetened drinks. No change in BMI occurred, and the authors attributed this to the short intervention time period. In summary, the community-based studies included one small study of a yoga intervention and four studies with specific ethnic groups: Portuguese, African American, and Hispanic students.

Clinic Interventions

Fifteen clinic-based interventions (Table 6) were delivered to children and adolescents aged 5–19 in a clinic setting and involved minimal family or group support (Coppen, Risser, & Vash, 2008; Davis et al., 2011, 2009, 2010, 2012; De Mello et al., 2011; Demol et al., 2008; Garanty-Bogacka et al., 2011; Mirza et al., 2013; Patrick et al., 2013; Reinehr et al., 2009; Smith, Annesi, Walsh, Lennon, & Bell, 2010; Szamosi et al., 2008; Ventura et al., 2009; Wickham et al., 2009). Clinic-based study authors reported the effectiveness of nutritional education and exercise either alone or in combination. Researchers of five articles reported results from the same large study involving nutritional education and strength training among adolescent Hispanics (Davis et al., 2011, 2009, 2010, 2012; Ventura et al., 2009). Together these researchers reported nutritional education and strength training were effective at improving metabolic and dietary measurements in adolescent Hispanics. They also concluded that a follow-up with monthly newsletters was sufficient for maintaining improvements. De Mello et al. (2011) in a similar study demonstrated that a combination of aerobic training and resistance training resulted in greater improvements in metabolic measurements compared to resistance training alone. Demol et al. (2008), researchers of adolescents in Israel, reported that nutritional education alone can result in long-term improvements in metabolic measurements. However, Patrick et al. (2013) employed a web-based health behavior change program with adolescents at "high risk" for diabetes in southern California. These students (aged 12–16, 74.3% Hispanic) did not demonstrate weight loss after 12 months of intervention. Garanty-Bogacka et al. (2011) and Reinehr, Kleber, and Toschke (2009) studied Polish and German youth and reported that behavior therapy in addition to nutritional education and physical activities were effective in improving metabolic measurements. Authors of four separate studies (Coppen et al., 2008; Smith et al., 2010; Szamosi et al., 2008; Wickham et al., 2009) one of which was with Hungarian youth, also reported improved metabolic measurements after interventions including nutritional education and physical activity. Only 4 of the 15 clinic-based articles included long-term follow-up measurements (Davis et al., 2011; Demol et al., 2008; Mirza et al., 2013; Patrick et al., 2013). Davis et al. (2011) and Demol et al. (2008) reported maintenance of metabolic improvements after 1 year. Mirza et al. (2013) reported no advantage between low glycemic diet or low fat diet for Hispanic youth after 2 years and both intervention groups improved cardiometabolic measures.

Summary

Researchers of nonpharmacological studies employed diverse intervention strategies; however, they all shared a few underlying foundational components. Common components of effective intervention strategies included different forms of physical activity, nutrition education, behavior therapy, cultural sensitivity, and ongoing support (via telephone sessions, newsletters, or periodic meetings). Other notable, but less common, components of intervention strategies included peer leadership opportunities, CST, and motivational interviewing.

Discussion

All students benefit from physical activity and caloric balance. Some students (obese, Hispanic, African American) are at increased risk for T2 DM. The challenge for the school nurse is to use scarce resources to apply research findings or to engage in research studies to prevent T2 DM. The objective of this systematic review was to determine effective characteristics of nonpharmacological interventions for reducing the risk of T2 DM in the youth population. Strengths and weaknesses of study design and method, outcome measures, effective characteristics of interventions, and barriers to implementation are discussed.

Strengths and Weaknesses of Study Design and Method

Together, the clinic-based studies demonstrated the most significant clinical results. The clinic-based studies included obese students who by their participation demonstrated a motivation to obtain study objectives. All of the clinic-based studies and four of the nonclinic-based studies (Damsgaard et al., 2013; Grey et al., 2009; Staiano et al., 2013; The HEALTHY Study Group, 2010) were randomized and controlled. Studies that included an entire school were less likely to demonstrate significant findings. However, not all participants in these interventions were overweight and this may have contributed to a decreased ability to demonstrate the intervention effect compared to clinic-based studies. Improved metabolic outcomes found in the real-world settings of the uncontrolled studies demonstrated the potential effectiveness of these interventions (e.g., Dorgan et al., 2011; Hogg et al., 2012; Raynor et al., 2012; Sharma & Fleming, 2012). Most uncontrolled studies compared outcome measures pre- and postintervention. Some of these studies were very small.

In general, interventions that included follow-up or continued opportunity for participation were most effective. However, length of intervention did not necessarily result in better outcomes. In Portugal, Pedrosa et al. (2010a, 2010b) demonstrated a brief lifestyle intervention with obese/overweight 7- to 9-year-olds and their parents resulting in a lasting effect measured at 3, 6, and 12 months. Many school-based interventions lasted 12 weeks and included 6 months of follow-up.

Outcome Measures

In addition to the large number and variety of outcome measures (Table 7), challenges to measurement of intervention effectiveness include that middle school-aged participants often experienced growth spurts during the study time frame. The impact of growth hormones on insulin resistance is a confounding variable in research of this type when performed without a control group (Bray & Bouchard, 2014). Therefore, BMI z scores are useful measures for all youth and indicated for middle school-aged children. Over time, weight loss and loss of waist size are clinically important outcome measures for older adolescents. In the short term, increased activity and decreased caloric consumption are appropriate process-oriented end points.

Studies generally did not discuss the clinical application of statistically significant outcomes. Instead, outcomes were likely to be framed in relation to known cardiac and/or metabolic risk. Following health behavior change, glucose measures may improve (e.g., insulin sensitivity, fasting glucose) prior to the more accessible measures (e.g., weight, BMI) of metabolic health (Bray & Bouchard, 2014).

Characteristics of Effective Interventions

Implications and considerations for the school nurse include evidence that subgroups of students benefited from interventions tailored to their interests. Cultural relevance, as well as frequent meetings (e.g., DeBar et al., 2011; Hogg et al., 2012; Shaibi et al., 2012; Staiano et al., 2013), played an important role in maintaining participation and preventing dropout. Activity (dance, walking, exergame) that is culturally relevant and made accessible to a large group of the youth participating was most effective (Hogg et al., 2012; Shaibi et al., 2012; Staiano et al., 2013). Strength training was more effective in boys than girls (Raman et al., 2010). Nutritional guidance was maintained with support from family and school (Burnet et al., 2011). Newsletters and other forms of social support including phone calls and/or text messaging improve health behavior maintenance (e.g., Grey et al., 2009). However, web-based interventions may not be enough to motivate behavior change (e.g., Patrick et al., 2013). Being involved as a peer educator strengthened healthy behavior (DeBar et al., 2011) as did participation in media communication (Schneider et al., 2013). Individualized health coaching in the clinic setting was effective with older adolescents (De Mello et al., 2011) as was a cooperative exergame for African American high school students (Staiano et al., 2013).

Although different study locations may be more effective for particular age groups, there were characteristics across the study locations that consistently contributed to significant results. Importantly, studies that provided time and space for physical activity and decreased access to calorie dense foods were more effective than education alone. Circuit training, exergame, and strength training improved metabolic health indicators (e.g., Davis et al., 2009, 2010, 2012). Also, ongoing support via telephone, newsletters, or meetings following intervention was associated with increased long-term maintenance (e.g., de Mello et al., 2011; Jefferson et al., 2011). Health coaching, CST, and behavior therapy were also effective in maintaining improvements in metabolic risk (e.g., Garanty-Bogacka et al., 2011; Reinehr et al., 2009).

Barriers to Implementation

Challenges to implementation of interventions to prevent T2 DM were discussed in several studies. Obtaining transportation to after-school community centers and poor school attendance were reported (e.g., Wofford et al., 2013). An advantage of the school setting as a location for intervention is the accessibility to children and adolescents within an established infrastructure (e.g., The HEALTHY Study Group, 2010; Wallén et al., 2013). The school setting also has the potential to provide motivational support from peers and teachers (e.g., Grey et al., 2009; Jefferson et al., 2011). But peer influence could be a disadvantage if overweight and obese youth experience stigma by feeling singled out through the intervention (Demol et al., 2008). In addition, potential disadvantages of school settings include poor school attendance, time away from school during summer and winter vacations, and lack of family involvement for ongoing support. Youth who did not have social support for behavior change did not demonstrate improvement in outcome measures (e.g., DeBar et al., 2011). However, researchers who incorporated some form of social support demonstrated improved metabolic outcomes (e.g., de Mello et al., 2011; Staiano et al., 2013).

An unreported barrier is the ongoing funding and training of personnel to support youth health initiatives. In addition, space for activities such as dance, yoga, and equipment such as the video exergame must be available. Guthrie and Newman (2013) reported that low-income students receive more than half of their daily calories from school food programs. New laws limiting the caloric and nutritional content of "competitive" foods sold at schools will likely benefit adolescent nutrition. However, it is not known how older students will respond to these initiatives. In addition to these environmental barriers, some benefits of long-term intervention were compromised as the novelty of the intervention wore off (e.g., Patrick et al., 2013). Identifying physical activity enjoyed by individuals and groups can be a challenge. For example, girls and boys benefit from strength training, but this activity may need to be framed in a discourse more acceptable to girls (e.g., Raman et al., 2010).

Conclusion

The school nurse is in a unique position to integrate findings from this review. The school is itself a community, intersects with the family, and may have clinic functions. This review reports on effective intervention strategies tailored to youth using a combination of characteristics (increasing activity, improving nutrition, and supporting behavior change). Insulin sensitivity is improved through physical activity and strength training. Student cardiometabolic measures improved with interventions that provided time and place for physical activity acceptable to youth (e.g., Staiano et al., 2013). β Cell function is preserved with dietary changes such as increasing dietary fiber and limiting high-sugar and high-fat foods (Bray & Bouchard, 2014). Strategies to support behavior change through use of mobile phone contact, peer counselors, and family involvement strengthened maintenance of healthy behavior (e.g., Jefferson et al., 2011). Most of the studies indicate that multifaceted strategies may be necessary to reduce the multifaceted metabolic risk for T2 DM in children and adolescents (e.g., Grey et al., 2009). Tables 3–6 provide the school nurse with a rich summary of each study included in this review. School nurses may select interventions appropriate to their school/student characteristics by examining these tables and reading promising studies further. School nurses are advised to design a T2 DM prevention program that includes activity/nutrition/social support to best benefit their students.

More research among youth at risk for future development of T2 DM is needed. Some studies included ethnic groups at a higher risk for T2 DM such as Hispanic youth (Davis et al., 2011, 2009, 2010, 2012; Mirza et al., 2013; Patrick et al., 2013; Shaibi et al., 2012; Ventura et al., 2009) and African American youth (Staiano et al., 2013; Wofford et al., 2013). In addition to ethnic groups, future research evaluating the effectiveness of interventions between boys and girls (Raman et al., 2010) as well as with high school-age participants in school-based settings is needed. An intervention acceptable to girls resulting in an increased muscle mass would improve insulin resistance, an important physiologic outcome. Measurement of intervention effect should include BMI z scores and measures of central obesity due to variations in BMI during periods of rapid growth (Bray & Bouchard, 2014). Long-term follow-up to measure the incidence of diabetes among study participants in a control group versus those experiencing the intervention would provide information on the ability of an intervention to achieve the major objective, T2 DM prevention (Dorgan et al., 2011). The ability to obtain research access to students at risk for T2 DM could be improved through the actions of the school nurse who understands these research gaps and communicates the need for further research to community leaders. The school is a practical interface between community, family, and clinic. The school nurse who understands the characteristics of effective interventions located in these settings can promote the achievement of these important health goals. The school nurse is able to navigate the academic setting promoting access to healthy nutritious foods, physical activity, and social environments supportive of T2 DM prevention for all students. The goal of improved health behavior is the delay of insulin resistance and preservation of pancreatic β cell function. The most desired outcome is absence of T2 DM symptoms until today's students are at least 40 years old. In this way, the school nurse can influence future health and the prevention of T2 DM for the next generation.

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