Preventing and Treating Type 2 Diabetes Through a Physically Active Lifestyle

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With type 2 diabetes exploding in the school population, physical educators can play an important role in countering the disease.

The decrease in time spent in quality physical education has serious implications that can influence the health and well-being of children. The trend today is to decrease time in physical education, or even eliminate it entirely from school curricula (Langford & Carter, 2003). The Centers for Disease Control and Prevention (CDC, 2006) found that participation in physical education has declined significantly among high school students. The CDC has also found that the activity level of children and adolescents declines as they get older and that the percentage of overweight young Americans has more than doubled in the last 30 years. Styne (1999) suggested that one reason for the increase in childhood obesity in the United States is the environmental changes that include reduction in physical education requirements. One of the major problems associated with childhood obesity is type 2 diabetes mellitus, which has become the most common form of diabetes diagnosed in children (Gungor, Hannon, Libman, Bacha, & Arslanian, 2005).

By the late 1960s, the increasing number of type 2 diabetic cases in children and adolescents rapidly presented a significant public health issue recognized by the American Diabetes Association (2000). Since then, the prevalence of pediatric type 2 diabetes appears to be on the rise not only in the United States but all around the world (Gungor et al., 2005). In the United States, an increase from fewer than four percent to more than 50 percent of new cases of type 2 diabetes in the pediatric population was reported between the years of 1982 and 1998 (American Diabetes Association, 2000). An increasing percentage of pediatric cases of newly diagnosed type 2 diabetes were also reported in population-based data (Gungor et al., 2005). Therefore, the purpose of this article is to discuss how regular physical activity can help to prevent and treat type 2 diabetes.

Scientific Insights

Diabetes mellitus is characterized by high blood sugar (technically, hyperglycemia). It is defined casually as a blood glucose level that is equal to or greater than 200 mg/dl. Since blood glucose level would fluctuate before and after a meal, clinical diabetes is diagnosed as an eight-hour fasting blood glucose concentration that is

equal to or greater than 126 mg/dl (American Diabetes Association, 2003). Diabetes can be classified into the following four categories: (a) type 1 diabetes; (b) type 2 diabetes; (c) gestational diabetes, which occurs in pregnant women but often disappears after pregnancy; and (d) others due to genetic abnormalities, medication use, and associated illnesses (American Diabetes Association, 2003). The two typical diabetic forms are non-insulin-dependent diabetes mellitus (NIDDM), commonly called type 2 diabetes, and insulin-dependent diabetes mellitus (IDDM), commonly called type 1 diabetes. In type 2 diabetes, individuals generally do not need insulin injections, because they can produce insulin but the body fails to use it efficiently. In type 1 diabetes, individuals do need insulin injections because their body cannot produce insulin. Type 2 diabetes is more prevalent, accounting for more than 90 percent of diabetic cases in the United States (American Diabetes Association, 2000, 2003).

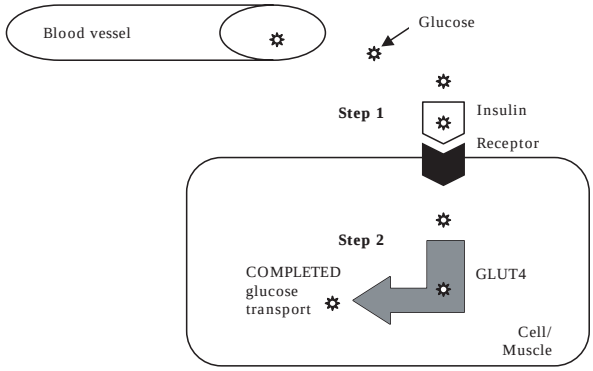
Glucose (a form of sugar) is always available in the bloodstream; however, that does not mean that the cells (or skeletal muscles) can use it. Glucose transport from bloodstream to cells occurs through a process called *facilitated diffusion*. Diffusion refers to the movement of molecules from the high-concentration to the low-concentration area. Facilitated diffusion refers to diffusion that requires a carrier to facilitate the process. For glucose transport, the carrier is called GLUT4, which is specifically a *glucose transporter carrier protein*. Glucose transport requires a complicated process of facilitated diffusion where glucose cannot enter the cell through the pores (holes) of the cell membrane because the size of glucose is larger than the pores. Therefore, it is critical to have GLUT4 to facilitate and complete the entire task of glucose transport to the cells for muscle utilization.

In simple words, blood sugar gains access to cells for muscle use through two steps (figure 1). Step one requires the presence of insulin and its receptor for diffusion to occur, while step two requires the GLUT4 glucose transporter to facilitate the completion of the entire diffusion process. For step one, insulin and its receptor have a key-and-lock relationship. Insulin is the key, and the insulin receptor is the lock. Insulin is essential to open the lock for glucose entry into cells for further processing. For step two, the GLUT4 glucose carrier is required to facilitate and complete the entire task of glucose transport into the cells. The GLUT4 can be compared to a shuttle that delivers glucose to the final destination for muscle use.

As seen in figure 1, it should be clear that the presence of insulin does not necessarily mean that glucose can enter the cells for muscle use if the insulin receptor (i.e., step 1) linking to the GLUT4 process (i.e., step 2) is defective. This defect is exactly the case in type 2 diabetes, in which insulin is available but the receptor linking to the GLUT4 process is defective. In the literature, this is often referred to as "insulin resistance" or "insulin receptor insensitivity." In simple words, patients have insulin but fail to use it. Consequently, the glucose level remains high in the bloodstream.

In early studies (Huycke & Kruhoffer, 1955; Holloszy & Narahara, 1965; Ivy & Holloszy, 1981), curiosity about the benefit of exercise on diabetes stirred interest in examining that relationship using animal models. Employing rats, dogs, and frogs as subjects, studies in the 1950s to 1980s examined the effects of exercise on glucose homeostasis (i.e., blood sugar balance). The findings mostly showed beneficial effects of exercise in diabetic animals, although some were controversial. More investigative work has subsequently been done on human subjects, and encouraging results were observed concerning the effects of exercise on diabetes in enhancing glucose regulation. Recently, specific research studies (Holloszy, 2005; Jessen & Goodyear, 2005) at the cellular and molecular levels have confirmed the importance of exercise to the improvement of glucose balance and regulation. These researchers have explained that exercise enhances the mobility of the GLUT4 glucose transporters, thereby improving insulin receptor sensitivity. As a result, the available insulin can be effectively utilized, and subsequently the available glucose can enter the cells for muscle use.

Figure 1. Simplified Mechanism of Glucose Transport from Bloodstream to Cells for Muscle Use



Implications for Physical Educators

Lifestyles such as a lack of physical activity, obesity, and high-fat diets are major causes for the development of type 2 diabetes. The good news is that all these conditions are mostly avoidable. Practicing healthy lifestyles that include increasing physical activity levels, maintaining desirable body weight, and choosing low-fat diets can significantly lower the risk of developing type 2 diabetes (Laakso, 2005).

There is strong evidence that type 2 diabetes can be prevented by an increase in physical activity even in high-risk diabetic individuals (Baumann, 2004). The Diabetes Prevention Program (Knowler et al., 2002) had more than 3,000 high-risk nondiabetic individuals randomly assigned to the following three groups: (a) exercise, (b) drug, and (c) control. The exercise group performed at least 150 minutes per week of moderate-intensity aerobic exercise. The drug group took 860 mg of metformin (a suppressor of glucose production)

Eating a well-balanced, low-fat diet (above) and engaging in regular physical activity (right) will help children avoid type 2 diabetes.

twice daily. The control group did not receive any treatment. The research was a longitudinal study lasting more than two years. The exercise and the drug groups were found to have a 58 percent and 31 percent lower incidence of diabetes, respectively, than the control group. Similar findings were observed in other racial and ethnic populations. An increase in physical activity level was found to lower the diabetic risk from 30 percent to 60 percent in Finnish (Laaksonen et al., 2005), Japanese (Kosaka, Noda, & Kuzuya, 2005), and Nigerian (Isezuo & Ezunu, 2005) subjects. Consistent with the above-mentioned studies, the prescription of mild-to-moderate-intensity aerobic exercise several times a week for a prolonged period of two to five years is frequently observed to be effective in the prevention of type 2 diabetes.

Regular exercise has a long-lasting effect on improved insulin sensitivity in type 2 diabetes, and some benefits can appear even after comparatively short periods of regular exercise. For example, in a study by Koivisto, Yki-Järvinen, and DeFronzo (1986), six weeks of exercise training increased insulin sensitivity by 25 percent to 35 percent. Diabetes is always associated with obesity, and the additional benefits of exercise include a better control of blood pressure, a decline in the LDL level (the "bad cholesterol," low-density lipoprotein), and a facilitation of weight management and general well-being.

Even though studies have shown that physical activity can have a positive impact on type 2 diabetes, children may be missing out on participating in physical activity due to low and declining participation in physical education (Lowry, Wechsler, Kann, & Collins, 2001). The CDC (2006) found that only 52 percent of high school students were enrolled in physical education, 32 percent attended physical education every day, and 76 percent of students enrolled in physical education were physically active for at least 20 minutes of their physical education classes. Lowry et al. (2001) found that participation among female and male students in high school physical education decreased significantly for every grade except 12th grade.

As a rule of thumb, *health and physical education teachers should encourage people to take proactive initiatives to prevent type 2 diabetes by engaging in regular physical activity before treatment becomes necessary.*

Exercise Guidelines for Type 2 Diabetics

For type 2 diabetic individuals, the goal of exercise is to improve insulin sensitivity. The American College of Sports Medicine (ACSM) has published a position statement recognizing that regular exercise serves as an imperative therapeutic modality for type 2 diabetes, although physical activity is often underutilized (Albright et al., 2000). Before starting an exercise program, individuals should check with their physician for medical screening. A graded exercise test is recommended for individuals over 35 years of age who have been diabetic for more than 10 years and are at high risk for underlying cardiovascular diseases such as autonomic neuropathy and vascular diseases (American Diabetes Association, 2005). According to the ACSM exercise guidelines

for type 2 diabetic individuals (Albright et al., 2000), the recommended types of physical activities should be those that can safely and effectively maximize caloric expenditure, such as walking or jogging, a convenient low-impact mode of physical activity for most people. Owing to potential complications such as peripheral neuropathy or arthritis in diabetic patients, non-weight-bearing activities such as biking or swimming should be considered as alternatives.

In terms of intensity, low-to-moderate-intensity physical activity is recommended. As type 2 diabetic individuals might start with a relatively low fitness level, a less intense aerobic activity allows a more comfortable level to begin and lessens the likelihood of musculoskeletal injuries such as foot trauma. The important fact is that low-intensity physical activity has been found to be adequate to produce favorable metabolic changes such as blood glucose reduction and insulin sensitivity enhancement (Albright et al., 2000; Holloszy, 2005). Regulation of exercise intensity is crucial because type 2 diabetic individuals may develop autonomic neuropathy (i.e., abnormal heart-rate responses to exercise). Therefore, heart-rate changes may not be proportional to exercise intensity increases. Using the rating-of-perceived-exertion scale (Borg, 1998) is suggested as an alternative when monitoring exercise intensity. In terms of the rate of progression, initial increases should focus on the *frequency* and *duration* of physical activity, rather than intensity, in order to provide a safe activity level to achieve the necessary level of energy expenditure (Albright et al., 2000).

For exercise frequency, daily aerobic exercise is recommended. If exercising every day is not feasible, a minimum of three to four exercise sessions per week is a must because the acute (short-term) glucose-lowering benefit of exercise lasts less than 72 hours. Therefore, the *regularity* of the exercise program should be emphasized, because regular, frequent, light exercise is better than occasional, strenuous, physical training.

For exercise duration, people should engage in at least 10 to 15 minutes of *continuous* exercise during each session. Ideally, 30 minutes of exercise is suggested to achieve a recommended energy expenditure level of 1,000 kcal/week. For beginners, exercise can be divided into three 10-minute sessions for an accumulative daily total of 30 minutes of exercise.

Physical education can be an excellent resource for children to get the physical activity needed to have a positive impact on type 2 diabetes. Children acquire approximately 20 to 40 percent of their physical activity at school (Simons-Morton, Taylor, Snider, & Huang, 1993). *Healthy People 2010* (U.S. Department of Health and Human Services [USDHHS], 2000) called for more physical education classes to provide students with the opportunity to engage in physical activities for at least 50 percent of the class time.

Theoretical and Practical Conclusions

From a scientific standpoint, significant progress has been made toward a better understanding of the molecular and cellular basis for the beneficial effects of exercise on type 2 diabetes. Understanding the underlying biological mechanisms can help health and physical educators formulate effective fitness strategies for the prevention and treatment of type 2 diabetes. Exercise exerts an "insulin-similar" effect for lowering the blood glucose level and enhances overall hormonal regulation. Hence, a regular exercise pattern emphasizing high-frequency excercise (preferably daily) of moderate duration (at least 15 minutes of continuous aerobic exercise per session) at low-to-moderate intensity is recommended for the purpose of preventing or treating type 2 diabetes.

With clear scientific evidence of the positive role of physical activity in enhancing glucose transport, one may question why so much time is spent on the *secondary medical treatment* of diabetes rather than on the *primary lifestyle preventive* approach to diabetes—which is an active engagement in physical activity! Physical education can play a vital role in educating people about the beneficial effects of physical activity on type 2 diabetes. The Surgeon General's report on physical activity and health (USDHHS, 1996) stated that "physical education is the most widely available resource for promoting physical activity among young people in the U.S. and every effort should be made to encourage schools to require daily physical education in each grade and to promote physical activities that can be enjoyed throughout life" (p. 6). No other discipline can have the same impact on the health and well-being of children than physical education (Langford & Carter, 2003). As a result, encouraging a lifelong physically active lifestyle should be the top priority in the joint efforts among health educators, physical educators, and medical professionals to help reduce the incidence of type 2 diabetes.

References

Albright, A., Franz, M., Hornsby, G., Kriska, A., Marrero, D., Ullrich, I., & Verity, L. S. (2000). Exercise and type 2 diabetes. *Medicine & Science in Sports & Exercise, 32*(7), 1345-1360.

American Diabetes Association. (2000). Type 2 diabetes in children and adolescents. *Pediatrics, 105,* 671-680.

American *Diabetes* Association. (2003). Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care, 26,* S5-S20.

American Diabetes Association. (2005). Clinical practice recommendations 2005. *Diabetes Care, 28*, S1-S79.

Baumann, A. E. (2004). Updating the evidence that physical activity is good for health: An epidemiological review 2000-2003. *Journal of Science and Medicine in Sport, 7*, 6-19.

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.

Centers for Disease Control and Prevention. (2006). *CDC's guidelines for school and community programs promoting lifelong physical activity*. Retrieved February 15, 2007, from http://www.cdc.gov/HealthyYouth/physicalactivity/promoting_health/strategies/school.htm.

Gungor, N., Hannon, T., Libman, I., Bacha, F., & Arslanian, S. (2005). Type 2 diabetes mellitus in youth: The complete picture to date.

Continues on page 54

constructivist classrooms. Alexandria, VA: Association for Supervision and Curriculum.

Brown, R. (1992). Max van Manen and pedagogical human science research. In W. Pinar & W. Reynolds (Eds.), *Understanding curriculum as phenomenological and deconstructed text* (pp. 44-63). New York: Teachers College Press.

Cone, T. P. (2002). *Off the page: Children's creative dance as a response to children's literature*. Ann Arbor, MI: UMI Dissertation Services.

Eisner, E. (1998). *The kind of schools we need: Personal essays*. Portsmouth, NH: Heinemann.

Emerson, R., Fretz, R., & Shaw, L. (1995). *Writing ethnographic fieldnotes*. Chicago: The University of Chicago Press.

Fraleigh, S. (1987). *Dance and the lived body: A descriptive aesthetics*. Pittsburgh, PA: University of Pittsburgh Press.

hooks, b. [*sic*] (1994). *Teaching to transgress: Education as the practice of freedom*. New York: Routledge.

Lather, P. (1991). *Getting smart: Feminist research and pedagogy with/in the postmodern*. New York: Routledge.

Marques, I. (1998). Dance education in/and the postmodern. In S. Shapiro (Ed.), *Dance, power and difference: Critical and feminist perspectives in dance education* (pp. 171-185). Champaign, IL: Human Kinetics.

Mirochnik, E. (2002). Celebration: The possibilities of passion. In E. Mirochnik & D. Sherman (Eds.), *Passion and pedagogy: Relation, creation and transformation in teaching* (pp. 7-36). New York: Peter Lang.

Mirochnik, E., & Sherman, D. (Eds.). (2002). *Passion and pedagogy: Relation, creation and transformation in teaching*. New York: Peter Lang.

Stinson, S., Blumenfield-Jones, D., & Van Dyke, J. (1990). Voices of young women dance students: An interpretive study of meaning in dance. *Dance Research Journal 22*(2), 13-22.

Stinson, S. (1988). *Dance for young children: Finding the magic in movement*. Reston, VA: American Alliance for Health, Physical Education, Recreation and Dance.

van Manen, M. (1993). *The tact of teaching: The meaning of pedagogical thoughtfulness*. London, Ontario, Canada: The Althouse Press.

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Leung

Continued from page 41

Pediatric Clinics of North America, 52(6), 1579-1609.

Holloszy, J. O. (2005). Exercise-induced increase in muscle insulin sensitivity. *Journal of Applied Physiology*, *99*(1), 338-343.

Holloszy, J. O., & Narahara, H. T. (1965). Changes in permeability to 3-methylglucose associated with contraction of isolated frog muscle. *The Journal of Biological Chemistry, 240*, 3493-3500.

Huycke, E., & Kruhoffer, P. (1955). Effects of insulin and muscular exercise upon the uptake of hexoses by muscle cells. *Acta Physiologica Scandinavica, 34,* 231-249.

Isezuo, S. A., & Ezunu, E. (2005). Demographic and clinical correlates of metabolic syndrome in native African type-2 diabetic patients. *Journal of the National Medical Association, 97*(4), 557-563.

Ivy, J. L., & Holloszy, J. O. (1981). Persistent increase in glucose uptake by rat skeletal muscle following exercise. *The American Journal of Physiology*, *241*(5), C200-C203.

Jessen, N., & Goodyear L. J. (2005). Contraction signaling to glucose transport in skeletal muscle. *Journal of Applied Physiology, 99*(1), 330-337.

Knowler, W. C., Barrett-Connor, E., Fowler, S. E., Hamman, R. F., Lachin, J. M., Walker, E. A., & Nathan, D. M. (2002). Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *The New England Journal of Medicine, 346*(6), 393-403.

Koivisto, V. A., Yki-Järvinen, H., & DeFronzo, R. A. (1986). Physical training and insulin sensitivity. *Diabetes/Metabolism Reviews*, *1*(4), 445-481.

Kosaka, K., Noda, M., & Kuzuya, T. (2005). Prevention of type 2 diabetes by lifestyle intervention: A Japanese trial in IGT males. *Diabetes Research and Clinical Practice*, *67*(2), 152-162.

Laakso, M. (2005). Prevention of type 2 diabetes. *Current Molecular Medicine*, *5*(3), 365-374.

Laaksonen, D. E., Lindström, J., Lakka, T. A., Eriksson, J. G., Niskanen, L., Wikström, K., Aunola, S., et al. (2005). Physical activity in the prevention of type 2 diabetes: the Finnish diabetes prevention study. *Diabetes, 54*(1), 158-165.

Langford, G. A., & Carter, L. (2003). Academic excellence must include physical education. *Physical Educator*, *60*(1), 28-33.

Lowry, R., Wechsler, H., Kann, L., & Collins, J. (2001). Recent trends in participation in physical education among U.S. high school students. *Journal of School Health*, *71*(4), 145-152.

Simons-Morton, B. G., Taylor, W. C., Snider, S. A., & Huang, I. W. (1993). The physical activity of fifth-grade students during physical education classes. *American Journal of Public Health*, *83*(2), 262-264.

Styne, D. M. (1999). Childhood obesity: time for action, not complacency. *American Family Physician*, *59*, 758-760.

U.S. Department of Health and Human Services. (1996). *Physical activity and health: A report of the Surgeon General*. Atlanta, GA: Centers for Disease Control and Prevention.

U.S. Department of Health and Human Services. (2000). *Healthy people 2010: National health promotion and disease prevention objectives*. Washington, DC: Author.

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