Physical Activity and the Prevention of Type II (Non–Insulin-Dependent) Diabetes

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ORIGINALLY PUBLISHED AS SERIES 2, NUMBER 10, OF THE PCPFS *RESEARCH DIGEST*.

HIGHLIGHT

"There is a strong link between type II diabetes and sedentary living. The biggest benefits appear to be found among those who incorporate some level of regular physical activity into their daily lives. Physical activity, as recommended by the Surgeon General, would seem to be a prudent strategy for all people, especially those who are at risk for type II diabetes."

A NOTE FROM THE EDITORS

According to the Surgeon General's report, as many as 8 million Americans know they have diabetes and at least 8 million more have diabetes but do not know it. More than 150,000 deaths each year are attributed to this condition. We asked Dr. Andrea Kriska, a researcher who studies diabetes, to write about this physical activity association.

There are two general classes of diabetes. As noted in the Surgeon General's Report, diabetes is a group of disorders that are associated with high blood sugar levels. "Insulin-dependent diabetes mellitus (IDDM or type I) is characterized by an absolute deficiency of circulating insulin...(page 125)." Non–insulin-dependent diabetes mellitus (NIDDM, or type II) is characterized by "elevated insulin levels that are ineffective in normalizing... blood sugar levels... or by impaired insulin secretion (page 125)." Because most cases of diabetes are of the second type (type II) and because physical activity has been shown to be more related to this type of disease, we have asked Dr. Kriska to focus on type II diabetes. In this paper, many questions about diabetes are answered and tables summarize key points. A list of basic definitions of key terms used in the paper is presented in Figure 11.1.

FIGURE 11.1

Basic definitions of key terms.

Insulin. A hormone secreted by the pancreas that regulates levels of sugar in the blood.

Insulin Resistance. A condition that occurs when insulin becomes ineffective or less effective than is necessary to regulate sugar levels in the blood.

Insulin Sensitivity. A person with insulin resistance (see above) is said to have decreased insulin sensitivity. The body's cells are not sensitive to insulin so they resist it and sugar levels are not regulated effectively.

Diabetes. A group of disorders that results in too much sugar in the blood, either because the body does not make enough insulin or makes insulin but cannot properly use it.

Oral Glucose Tolerance Test. A test to determine if a person is diabetic. The test measures the body's ability to clear sugar from the blood in a reasonable time after having taken a standardized oral dose of glucose (sugar).

Blood Glucose. Sugar levels in the blood.

WHAT IS TYPE II DIABETES?

Diabetes can be defined simply and succinctly as "too much glucose in the blood" (West, 1978). It is a devastating disease that can often lead to complications such as blindness, kidney failure, coronary heart disease, circulatory problems that may result in amputation, nerve problems, and premature death.

Among those with diabetes, type II is the most common type, accounting for 90–95% of all diabetic cases and affecting about 7% of the US population (DIA; Harris, 1987). Among those with type II diabetes, most (60–90%) but not all are obese when the disease is diagnosed (National Diabetes Data Group, 1979). Symptoms that are usually associated with the onset of type II diabetes are the direct result of the high blood glucose, although in many milder cases of diabetes, there may not be any symptoms (West, 1978). In fact, it has been estimated that the number of individuals in the general population who are not aware that they have type II diabetes is equal to the number of individuals who have been diagnosed with the disease (Harris, 1995).

Just as hypertension is diagnosed at the upper end of a blood pressure distribution, the diagnosis of diabetes is usually made at the upper end of a continuum of blood glucose values. Typically, the diagnosis of type II diabetes is determined based upon a specific test administered in a fasting state (an oral glucose tolerance test) in which the blood glucose values are measured two hours after drinking a specific glucose solution (WHO, 1980). An individual is considered to have diabetes if the blood glucose values two hours after drinking the mixture are 11.1 mmol/l or greater. Just as someone with borderline blood pressure values are at high risk for hypertension, an individual is considered to be at risk for diabetes if his/her blood glucose values two hours after drinking the solution are 7.8–11.0 mmol/l, which is called impaired glucose tolerance (WHO, 1980).

Despite the fact that type II diabetes is a complex condition caused by both genetic and behavioral factors, the basic metabolic abnormalities responsible for the high blood glucose values are resistance of the body's cells to the action of insulin (termed insulin resistance or decreased insulin sensitivity) and the inability of the pancreas to secrete enough insulin to meet the glucose demand (termed insulin deficiency). During the early stages of the disease development in a genetically prone individual, insulin resistance of the insulin-sensitive tissues of the body (muscles and liver) can usually be found (DeFronzo, 1992). Being insulin resistant means that the glucose cannot readily enter the cells, resulting in a rise of blood glucose concentrations. This increase in blood glucose causes the pancreas to secrete more insulin in an attempt to normalize the blood glucose levels. If allowed to continue, this cycle of resistance and secretion proceeds until the amount of insulin that is secreted is no longer sufficient to compensate for an extreme amount of tissue insulin resistance, resulting in elevated blood glucose values and eventually diabetes (Saad, 1988; Knowler, 1995).

WHAT IS THE PHYSIOLOGICAL BASIS BEHIND A POTENTIAL RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND THE PREVENTION OF TYPE II DIABETES?

Various reviews of the effects of physical activity on insulin resistance and glucose tolerance have identified the physiological reasons why a relationship between physical activity and type II diabetes is possible (Vranic, 1979; Björntorp, 1985; Koivisto, 1986; Lampman, 1991; Horton, 1991; Wallberg-Henriksson, 1992; Zierath, 1992). In general, active individuals have better insulin and glucose profiles than their inactive counterparts (Stevenson, 1995; Lohmann, 1978) with detraining and bed rest shown to deteriorate these metabolic parameters (Lipmann, 1972; Heath, 1983). Equally as convincing, exercise training studies have found physical activity to improve insulin action or, in other words, decrease insulin resistance (Saltin, 1979; Lindgärde, 1983; Krotkiewski, 1983; Trovati, 1984; Schneider, 1984; Seals, 1984; Rönnemaa, 1986). Less consistently, some exercise training studies have also found activity to improve glucose metabolism in both normal individuals and those with mild type II diabetes (Minuk, 1981; Holloszy, 1986). Based upon the findings of these training studies, it appears that physical activity would most likely impact on insulin action in individuals at high risk for diabetes (with hyperinsulinemia), that is, those individuals whose capacity to secrete insulin is still intact and insulin resistance is the major cause of the abnormal glucose tolerance (Holloszy, 1986).

Obesity and fat distribution (specifically, the distribution of body fat in the central as compared to the peripheral regions) are major contributors to insulin resistance and are therefore, strongly involved in the pathogenesis of type II diabetes (Björntorp, 1988; Björntorp, 1991; Dowse, 1991; Haffner, 1986; Hartz, 1983; Kissebah, 1989; Knowler, 1991; Modan, 1986; Ohlson, 1985; Stern, 1991). Physical activity has also been shown to be inversely associated with obesity and central fat distribution, with studies demonstrating that physical training can reduce both of these parameters (Björntorp, 1979; Brownell, 1980; Despres, 1988; Krotkiewski, 1988). In other words, it is feasible that physical activity may also prevent or delay type II diabetes through decreasing overall fat and/or intra-abdominal fat.

In summary, it appears that physical activity may not only be related to type II diabetes directly but also indirectly through obesity. Since most individuals with type II diabetes are obese, and change in activity is often associated with small but important changes in fat and body composition, complete separation of the effects of activity from the effects of body composition on type II diabetes is often difficult (Schwartz, 1997). However, clinical studies examining the effects of physical training on patients with type II diabetes have suggested a direct relationship between the two, independent of obesity.

FIGURE 11.2

Possible mechanisms through which physical activity may prevent or delay the development of type II diabetes.

- Decrease insulin resistance/improve insulin sensitivity
- Improve blood glucose levels (glucose tolerance)
- Decrease overall adiposity
- Reduce central adiposity
- Desirable changes in muscle tissue

DO EPIDEMIOLOGY STUDIES SUPPORT A RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND TYPE II DIABETES?

Through the years, from early observations to current epidemiological studies, support for the existence of a relationship between physical activity and type II diabetes has been increasing. Suggestions of a relationship between physical activity and type II diabetes were supported early on by the fact that societies that had abandoned traditional lifestyles (which typically had included large amounts of habitual physical activity) had experienced major increases in type II diabetes (West, 1978). Indirect evidence of this phenomenon was also provided by the observation that groups of subjects who migrated to a more modern environment had more diabetes than their ethnic counterparts who remained in their native land (Hara, 1983; Kawate, 1979; Ravussin, 1994) or that rural dwellers had a lower prevalence of diabetes than their urban counterparts (Cruz-vidal, 1979; Zimmet, 1981; Zimmet, 1983; King, 1984). In these studies, differences in physical activity were suggested as partial explanations for the differences in diabetes prevalence. Results of epidemiology studies are described in the following sections and summarized in Figure 11.3.

FIGURE 11.3

Epidemiological studies supporting the relationship between physical activity and type II diabetes.

Cross-sectional Study: Both diabetes status (and glucose/insulin levels) and physical activity levels are determined at the same point in time in the same individuals.

- Individuals with type II diabetes are less active than those without diabetes.

- Among those without type II diabetes, more active individuals have lower glucose and insulin values than their inactive counterparts.

Case-Control (or Retrospective) Study: Individuals with and without type II diabetes are asked questions about their past, in this case, their physical activity levels.

- Individuals with type II diabetes reported less physical activity over their lifetime than individuals without diabetes.

Prospective or Longitudinal Study: Inactive and active individuals without type II diabetes are followed over time to determine if physical activity levels play a role in determining who will and will not develop the disease.

- Women alumnae who were former college athletes had a lower prevalence of diabetes than those who were nonathletes.
- For men and women alike, individuals who are relatively more physically active are less likely to develop type II diabetes in the future than those who are sedentary.

Experimental Study or Clinical Trial: Individuals free of type II diabetes are randomly assigned to a group that includes a physical activity program or does not include it. Follow-up of these groups over time will examine which group develops more diabetes in the future.

- Individuals assigned to the group that includes a physical activity program developed less diabetes over time than those who were not assigned to the activity group.

Cross-sectional studies collect information about the health outcome (glucose intolerance or type II diabetes) and the potential risk factor (physical inactivity) at the same time within the same group. This type of epidemiological design is limited because it is not possible to establish causality; i.e., did inactivity cause the glucose intolerance or did the condition cause the inactivity.

Cross-sectional epidemiological studies have shown that physical inactivity was associated with type II diabetes and glucose intolerance within populations. Groups of subjects with type II diabetes were found to be less active currently (Taylor, 1983; Taylor, 1984; King, 1984; Dowse, 1990; Ramaiya, 1991; Kriska, 1993) than nondiabetic persons. In addition, cross-sectional studies that have examined the relationship between physical activity and glucose intolerance in individuals without type II diabetes generally showed that blood glucose values after an oral glucose tolerance test (Lindgärde, 1981; Cederholm, 1985; Wang, 1989; Schranz, 1991; Dowse, 1991; Kriska, 1993; Periera, 1995) as well as insulin values (Lindgärde, 1981; Wang, 1989; Dowse, 1991; McKeigue, 1992; Feskens, 1994; Regensteiner, 1995) were significantly higher in the less active compared to the more active individuals.

In case-control (or retrospective) study designs, individuals with and without diabetes are asked questions about their past, particularly their exposure to the specific risk factor in question (i.e., physical activity level). Although this type of study design is valuable in cases where the disease outcome is rare, it does suffer from potential recall bias, in which the diseased or high-risk individual may remember or recall past events differently. An example of this type of study design was demonstrated in the Pima Indian Study in which those individuals from the Gila River Indian Community with diabetes reported less physical activity over their lifetime than individuals without diabetes (Kriska, 1993).

The most powerful observational study design is the **prospective or longitudinal study design.** This particular design identifies and follows individuals initially free of the health outcome of interest (diabetes) and seeks to establish if initial or subsequent physical activity levels differentiate those who do and do not develop the disease.

The fact that a sedentary lifestyle may play a role in the development of type II diabetes has been demonstrated in prospective studies of college alumni, registered nurses, physicians, and middle-aged British men (Helmrich, 1991; Manson, 1991, 1992; Perry, 1995). Women alumnae who were former college athletes had a lower prevalence of diabetes than those who were nonathletes (Frisch, 1986). A study of male alumni from the University of Pennsylvania (Helmrich, 1991) demonstrated that physical activity was inversely related to the incidence of type II diabetes, a relationship that was particularly evident in men at high risk for developing diabetes (defined as those with a high body mass index, a history of hypertension, or a parental history of diabetes). In a study of female registered nurses aged 34–59 years, women who reported engaging in vigorous exercise at least once a week had a lower incidence of self-reported type II diabetes during the eight years of follow-up than women who did not exercise weekly (Manson, 1991). Similar findings were observed between exercise and incidence of type II diabetes in a five-year prospective study of 40–84-year-old male physicians (Manson, 1992). Finally, the risk of developing diabetes over a 13-year period was reduced by 50% in men engaged in moderate to vigorous levels of physical activity compared to the less active men (Perry, 1995). Although the results of all of these prospective epidemiological studies suggest a causal relationship between physical inactivity and type II diabetes, the strength of their findings is weakened due to the determination of diabetes based upon self-report rather than an oral glucose tolerance test (since an estimated 50% of the general population are not aware that they have type II diabetes).

Similar to measures of physical activity, physical fitness as determined by maximal oxygen uptake or as estimated by vital capacity also appears to play a role in the development of type II diabetes (Eriksson, 1996, 1991). In addition, support that physical fitness may provide some protection against mortality in men at all levels of glucose intolerance (from those with normal blood glucose to those with type II diabetes) was demonstrated in middle-aged men (Kohl, 1992).

Physical activity was a major part of the intervention strategy of a feasibility trial of diabetes prevention in 47–49-year-old men from Malmo, Sweden. Of those with impaired glucose intolerance at baseline, at least twice as many of those who did not take part in the treatment program had developed diabetes at the five-year follow-up compared with those who participated (Eriksson, 1991). However, since the participants were **not** randomly assigned to the intervention treatment groups, and since the treatment groups differed by medical condition at baseline, the results of this study are not conclusive. In other words, the hypothesis that physical activity intervention may prevent type II diabetes was not adequately tested.

The most powerful and by far the most labor-intensive epidemiological study design is the **experimental design or clinical trial** in which efforts are made to prevent or delay the onset of the type II diabetes by manipulating the risk factor of interest, in this case, physical activity levels. In this design, individuals free of type II diabetes would be randomly assigned to receive either the intervention (the physical activity intervention group) or no intervention (the control group). Subsequent follow-up of the two groups over time would determine if the groups differ by the percent who eventually develop the disease outcome.

Results of a more recent clinical trial demonstrated that physical activity intervention led to a decrease in the incidence of diabetes over a six-year period among Chinese individuals initially identified with impaired glucose tolerance (Pan, 1997). At the beginning of the study, 577 individuals with impaired glucose tolerance were identified from a citywide health screening in DaQing and randomized by clinic into one of four groups: exercise only, diet only, diet plus exercise and a control group. Individuals assigned to the exercise group were encouraged to increase their daily leisure physical activity to that comparable to a 30-minute walk. The percent that developed diabetes was significantly lower in each of the three intervention groups compared to the control group (exercise = 44%, diet = 47%, exercise plus diet = 44%, control = 66%).

An example of a randomized, multi-center clinical trial of type II diabetes prevention that incorporates physical activity as one of the possible treatments is currently underway in the United States (Diabetes Prevention Program, sponsored by the National Institutes of Health; NIH, 1993). In this trial, physical activity is combined with dietary modification to comprise the lifestyle intervention arm of the study. Anyone interested in participating in the Diabetes Prevention Program and/or wants to obtain more information about the program should call the following toll-free number (1-888-DDP-JOIN).

PHYSICAL ACTIVITY RECOMMENDATIONS: HOW MUCH IS ENOUGH?

Recent national physical activity recommendations and summary statements suggest that the majority of overall health benefits from physical activity are gained by performing activities that are not necessarily of high intensity (Pate, 1995). In fact, it has been suggested that the sedentary individual who begins to incorporate adequate amounts of **moderate levels** of physical activity into his/her lifestyle such as walking and gardening may attain substantial health benefits and reduce cardiovascular disease risk (Pate, 1995). How can we best incorporate physical activity into our lifestyle to maximize the health benefits specific to type II diabetes?

Type of Physical Activity Recommended

Most of the exercise training and epidemiology studies done to date have focused on aerobic types of activity that require the use of large muscle mass such as walking, running, and biking. Aerobic activities are recommended for the overall public as the primary type of activity because of their potential benefits in regards to improving the type II diabetes and cardiovascular risk profile (Surgeon General’s Report, 1996).

Recently, the benefits of incorporating strength training into an overall activity regimen (that includes aerobic activity) for the prevention and treatment of type II diabetes are being recognized. Strength training has been shown to acutely improve glucose tolerance and insulin sensitivity in individuals with both normal and abnormal glucose tolerance (Smutok, 1994; Miller, 1994).

Frequency/Duration of Physical Activity Recommended

A substantial part of the improvements in glucose tolerance and insulin resistance due to exercise are believed to be the result of the cumulative effect of a frequent lowering of the blood glucose levels and decreasing insulin resistance with each specific bout of exercise (Schneider, 1984). In fact, it appears that a large portion of the effect of exercise in decreasing insulin resistance is short-lived, lasting for a few days, whereas the blood glucose lowering effect of activity may not even last that long (Heath, 1983; Koivisto, 1986). Possible additional improvements in glucose tolerance and insulin resistance due to a training effect of regular exercise on these parameters have been suggested as well (Young, 1989).

In addition, the adaptation caused by increased levels of physical activity that can have an impact on insulin resistance over the long term (especially in the older adult) is the change in body composition. This is in light of the fact that a very critical individual goal in regards to glucose intolerance is to attain and maintain an appropriate weight. Physical activity, in conjunction with diet, appears to be the best combination for decreasing weight (preferentially decreasing centrally distributed fat) and to improving glucose tolerance and insulin sensitivity (Yamanouchi, 1995). Furthermore, physical activity has been shown to play an important role in long-term weight maintenance (Wing, 1988; Pavlou, 1989).

Based upon the information provided above, at what frequency should one attempt exercise throughout the week? Since one of the goals for incorporating physical activity into one’s lifestyle is to “burn more calories,” and since a substantial portion of the improvement in insulin and glucose appears to be short-lived, it seems reasonable to recommend a frequency of exercise of several times per week. In other words, the weekend exerciser should strongly consider adding a few extra bouts of physical activity throughout the week to maximize his/her benefits in regards to glucose tolerance and insulin sensitivity (not to mention the fact that it is safer from a cardiovascular risk point of view).

Intensity of Physical Activity Recommended

In regards to insulin sensitivity and glucose tolerance, physical training studies suggest that higher intensity exercises are more likely to bring about the desired metabolic changes than lower intensity activities (Holloszy, 1986; Seals, 1984). Lower intensity activities appear to follow in the same general direction, although the onset of the effects are much slower and less dramatic (Björntorp, 1995).

In regards to caloric expenditure, intensity of activity is not an issue. The important thing is that activity is being done! In general, lower intensity activities are usually easier to adopt in one’s lifestyle and are relatively less likely to result in injury (Pollock, 1991). It is recommended that beginners start any physical activity slowly and gradually speed up the pace and build up the duration over time.

Finally, it appears that the largest and most consistent difference in risk of type II diabetes occurs between those individuals who report relatively no activity and those who report doing something (see the review by Kriska, 1994). This would suggest that the individuals who would benefit the most from any public health effort to prevent type II diabetes would be the sedentary individuals. If you are currently sedentary, or know people who do not incorporate activity into their lifestyle with any regularity, now is the time, and here is the reason, to begin to incorporate moderate levels of physical activity such as walking and gardening. If you have diabetes or coronary heart disease, it is suggested that you talk with your physician before increasing your activity level (ADA Council on Exercise, 1990; Schwartz, 1997). If you are already active, keep up the good work.

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