

Insulin Resistance and Prediabetes

What is insulin?

Insulin is a hormone made in the pancreas, an organ located behind the stomach. The pancreas contains clusters of cells called islets. Beta cells within the islets make insulin and release it into the blood.

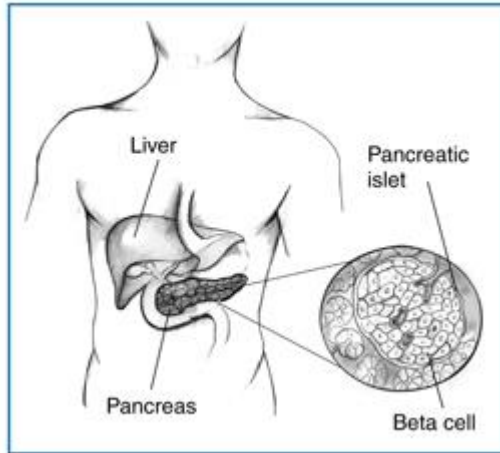
Insulin plays a major role in metabolism—the way the body uses digested food for energy. The digestive tract breaks down carbohydrates—sugars and starches found in many foods—into glucose. Glucose is a form of sugar that enters the bloodstream. With the help of insulin, cells throughout the body absorb glucose and use it for energy.

Insulin's Role in Blood Glucose Control

When blood glucose levels rise after a meal, the pancreas releases insulin into the blood. Insulin and glucose then travel in the blood to cells throughout the body.

- Insulin helps muscle, fat, and liver cells absorb glucose from the bloodstream, lowering blood glucose levels.
- Insulin stimulates the liver and muscle tissue to store excess glucose. The stored form of glucose is called glycogen.
- Insulin also lowers blood glucose levels by reducing glucose production in the liver.

In a healthy person, these functions allow blood glucose and insulin levels to remain in the normal range.



The pancreas contains clusters of cells called islets. Beta cells within the islets make insulin and release it into the blood.

What is insulin resistance?

Insulin resistance is a condition in which the body produces insulin but does not use it effectively. When people have insulin resistance, glucose builds up in the blood instead of being absorbed by the cells, leading to type 2 diabetes or prediabetes.

Most people with insulin resistance don't know they have it for many years—until they develop type 2 diabetes, a serious, lifelong disease. The good news is that if people learn they have insulin resistance early on, they can often prevent or delay diabetes by making changes to their lifestyle.

Insulin resistance can lead to a variety of serious health disorders. The section [“What is metabolic syndrome?”](#) provides more information about other health disorders linked to insulin resistance.

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What happens with insulin resistance?

In insulin resistance, muscle, fat, and liver cells do not respond properly to insulin and thus cannot easily absorb glucose from the bloodstream. As a result, the body needs higher levels of insulin to help glucose enter cells.

The beta cells in the pancreas try to keep up with this increased demand for insulin by producing more. As long as the beta cells are able to produce enough insulin to overcome the insulin resistance, blood glucose levels stay in the healthy range.

Over time, insulin resistance can lead to type 2 diabetes and prediabetes because the beta cells fail to keep up with the body's increased need for insulin. Without enough insulin, excess glucose builds up in the bloodstream, leading to diabetes, prediabetes, and other serious health disorders.

What causes insulin resistance?

Although the exact causes of insulin resistance are not completely understood, scientists think the major contributors to insulin resistance are excess weight and physical inactivity.

Excess Weight

Some experts believe obesity, especially excess fat around the waist, is a primary cause of insulin resistance. Scientists used to think that fat tissue functioned solely as energy storage. However, studies have shown that belly fat produces hormones and other substances that can cause serious health problems such as insulin resistance, high blood pressure, imbalanced cholesterol, and cardiovascular disease (CVD).

Belly fat plays a part in developing chronic, or long-lasting, inflammation in the body. Chronic inflammation can damage the body over time, without any signs or symptoms. Scientists have found that complex interactions in fat tissue draw immune cells to the area and trigger low-level chronic inflammation. This inflammation can contribute to the development of insulin resistance, type 2 diabetes, and CVD. Studies show that losing the weight can reduce insulin resistance and prevent or delay type 2 diabetes.

Physical Inactivity

Many studies have shown that physical inactivity is associated with insulin resistance, often leading to type 2 diabetes. In the body, more glucose is used by muscle than other tissues. Normally, active muscles burn their stored glucose for energy and refill their

reserves with glucose taken from the bloodstream, keeping blood glucose levels in balance.

Studies show that after exercising, muscles become more sensitive to insulin, reversing insulin resistance and lowering blood glucose levels. Exercise also helps muscles absorb more glucose without the need for insulin. The more muscle a body has, the more glucose it can burn to control blood glucose levels.

Other Causes

Other causes of insulin resistance may include ethnicity; certain diseases; hormones; steroid use; some medications; older age; sleep problems, especially sleep apnea; and cigarette smoking.

Does sleep matter?

Yes. Studies show that untreated sleep problems, especially sleep apnea, can increase the risk of obesity, insulin resistance, and type 2 diabetes. Night shift workers may also be at increased risk for these problems. Sleep apnea is a common disorder in which a person's breathing is interrupted during sleep. People may often move out of deep sleep and into light sleep when their breathing pauses or becomes shallow. This results in poor sleep quality that causes problem sleepiness, or excessive tiredness, during the day.

Many people aren't aware of their symptoms and aren't diagnosed. People who think they might have sleep problems should talk with their health care provider.

What is prediabetes?

Prediabetes is a condition in which blood glucose or A1C levels—which reflect average blood glucose levels—are higher than normal but not high enough for a diagnosis of diabetes. Prediabetes is becoming more common in the United States. The U.S. Department of Health and Human Services estimates that at least 86 million U.S. adults ages 20 or older had prediabetes in 2012.¹ People with prediabetes are at increased risk of developing type 2 diabetes and CVD, which can lead to heart attack or stroke.

How does insulin resistance relate to type 2 diabetes and prediabetes?

Insulin resistance increases the risk of developing type 2 diabetes and prediabetes. Prediabetes usually occurs in people who already have insulin resistance. Although insulin resistance alone does not cause type 2 diabetes, it often sets the stage for the disease by placing a high demand on the insulin-producing beta cells. In prediabetes, the beta cells can no longer produce enough insulin to overcome insulin resistance, causing blood glucose levels to rise above the normal range.

Once a person has prediabetes, continued loss of beta cell function usually leads to type 2 diabetes. People with type 2 diabetes have high blood glucose. Over time, high blood glucose damages nerves and blood vessels, leading to complications such as heart disease, stroke, blindness, kidney failure, and lower-limb amputations.

Studies have shown that most people with prediabetes develop type 2 diabetes within 10 years, unless they change their lifestyle. Lifestyle changes include losing 5 to 7 percent of their body weight—10 to 14 pounds for people who weigh 200 pounds—by making changes in their diet and level of physical activity.



What are the symptoms of insulin resistance and prediabetes?

Insulin resistance and prediabetes usually have no symptoms. People may have one or both conditions for several years without knowing they have them. Even without symptoms, health care providers can identify people at high risk by their physical characteristics, also known as risk factors.

People with a severe form of insulin resistance may have dark patches of skin, usually on the back of the neck. Sometimes people have a dark ring around their neck. Dark patches may also appear on elbows, knees, knuckles, and armpits. This condition is called acanthosis nigricans.

Who should be tested for prediabetes?

The American Diabetes Association (ADA) recommends that testing to detect prediabetes be considered in adults who are overweight or obese and have one or more additional risk factors for diabetes. The section "[Body Mass Index \(BMI\)](#)" explains how to determine if a person is overweight or obese. However, not everyone who is overweight will get type 2 diabetes. People without these risk factors should begin testing at age 45.

Risk factors for prediabetes—in addition to being overweight or obese or being age 45 or older—include the following:

- being physically inactive
- having a parent or sibling with diabetes
- having a family background that is African American, Alaska Native, American Indian, Asian American, Hispanic/Latino, or Pacific Islander American
- giving birth to a baby weighing more than 9 pounds
- being diagnosed with gestational diabetes—diabetes that develops only during pregnancy
- having high blood pressure—140/90 mmHg or above—or being treated for high blood pressure
- HDL cholesterol level below 35 mg/dL or a triglyceride level above 250 mg/dL
- having polycystic ovary syndrome (PCOS)
- having prediabetes, impaired fasting glucose (IFG), or impaired glucose tolerance (IGT) on an earlier testing

- having other conditions associated with insulin resistance, such as obesity or acanthosis nigricans
- having CVD

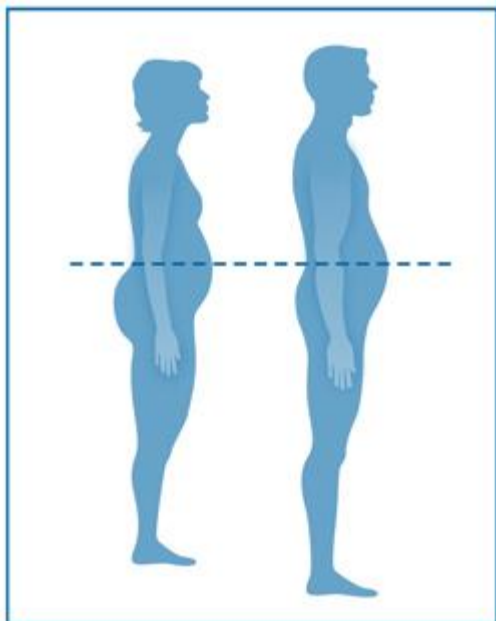
If test results are normal, testing should be repeated at least every 3 years. Testing is important for early diagnosis. Catching prediabetes early gives people time to change their lifestyle and prevent type 2 diabetes and CVD. Health care providers may recommend more frequent testing depending on initial results and risk status.

In addition to weight, the location of excess fat on the body can be important. A waist measurement of 40 inches or more for men and 35 inches or more for women is linked to insulin resistance and increases a person's risk for type 2 diabetes. This is true even if a person's BMI falls within the normal range.

How to Measure the Waist

To measure the waist, a person should

- place a tape measure around the bare abdomen just above the hip bone
- make sure the tape is snug but isn't digging into the skin and is parallel to the floor
- relax, exhale, and measure



Source: Adapted from www.cdc.gov.

Body Mass Index (BMI)

Body mass index is a measurement of body weight relative to height. Adults ages 20 or older can follow the steps below using the BMI chart to find out whether they are normal weight, overweight, or obese:

- People should find their height in the left-hand column.
- They should move across the row to the number closest to their weight.
- Then, they should check the number at the top of that column.

The number at the top of the column is the BMI. The words above the BMI number indicate whether that person is normal weight, overweight, or obese. People who are overweight or obese should consider talking with a health care provider or registered dietitian about ways to lose weight to reduce the risk of diabetes.

The BMI chart has certain limitations. The chart may overestimate body fat in athletes and others who have a muscular build and underestimate body fat in older adults and

others who have lost muscle. BMI for children and teens must be determined based on age and sex in addition to height and weight.

Body Mass Index Table

[Printer-friendly version \(PDF, 70 KB\)](#) * Body Mass Index Table 1 of 2

	Normal						Overweight					Obese					
BMI	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Height (inches)	Body Weight (pounds)																
58	91	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167
59	94	99	104	109	114	119	124	128	133	138	143	148	153	158	163	168	173
60	97	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179
61	100	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185
62	104	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191
63	107	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197
64	110	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204
65	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210
66	118	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216
67	121	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223
68	125	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230
69	128	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236
70	132	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243
71	136	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	250
72	140	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258
73	144	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265
74	148	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272
75	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	279
76	156	164	172	180	189	197	205	213	221	230	238	246	254	263	271	279	287

Body Mass Index Table 2 of 2

	Obese				Extreme Obesity														
BMI	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

Height (inches)	Body Weight (pounds)																			
	172	177	181	186	191	196	201	205	210	215	220	224	229	234	239	244	248	253	258	263
58	172	177	181	186	191	196	201	205	210	215	220	224	229	234	239	244	248	253	258	263
59	178	183	188	193	198	203	208	212	217	222	226	231	236	241	246	251	256	261	266	271
60	184	189	194	199	204	209	214	218	223	228	233	238	243	248	253	258	263	268	273	278
61	190	195	200	205	210	215	220	224	229	234	239	244	249	254	259	264	269	274	279	284
62	196	201	206	211	216	221	226	230	235	240	245	250	255	260	265	270	275	280	285	290
63	202	207	212	217	222	227	232	236	241	246	251	256	261	266	271	276	281	286	291	296
64	208	213	218	223	228	233	238	242	247	252	257	262	267	272	277	282	287	292	297	302
65	214	219	224	229	234	239	244	248	253	258	263	268	273	278	283	288	293	298	303	308
66	220	225	230	235	240	245	250	254	259	264	269	274	279	284	289	294	299	304	309	314
67	226	231	236	241	246	251	256	260	265	270	275	280	285	290	295	300	305	310	315	320
68	232	237	242	247	252	257	262	266	271	276	281	286	291	296	301	306	311	316	321	326
69	238	243	248	253	258	263	268	272	277	282	287	292	297	302	307	312	317	322	327	332
70	244	249	254	259	264	269	274	278	283	288	293	298	303	308	313	318	323	328	333	338
71	250	255	260	265	270	275	280	284	289	294	299	304	309	314	319	324	329	334	339	344
72	256	261	266	271	276	281	286	290	295	300	305	310	315	320	325	330	335	340	345	350
73	262	267	272	277	282	287	292	296	301	306	311	316	321	326	331	336	341	346	351	356
74	268	273	278	283	288	293	298	302	307	312	317	322	327	332	337	342	347	352	357	362
75	274	279	284	289	294	299	304	308	313	318	323	328	333	338	343	348	353	358	363	368
76	280	285	290	295	300	305	310	314	319	324	329	334	339	344	349	354	359	364	369	374

	Obese				Extreme Obesity														
BMI	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Height (inches)	Body Weight (pounds)																		
	5	4	2	0	8	6	4	3	1	9	7	5	4	2	0	8	6	5	3

Source: Adapted from *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report*, National Institutes of Health, 1998.

What is metabolic syndrome?

Metabolic syndrome, also called insulin resistance syndrome, is a group of traits and medical conditions linked to overweight and obesity that puts people at risk for both CVD and type 2 diabetes. Metabolic syndrome is defined* as the presence of any three of the following²:

- **large waist size**—waist measurement of 40 inches or more for men and 35 inches or more for women
- **high triglycerides in the blood**—triglyceride level of 150 milligrams per deciliter (mg/dL) or above, or taking medication for elevated triglyceride level
- **abnormal levels of cholesterol in the blood**—HDL, or good, cholesterol level below 40 mg/dL for men and below 50 mg/dL for women, or taking medication for low HDL
- **high blood pressure**—blood pressure level of 130/85 or above, or taking medication for elevated blood pressure
- **higher than normal blood glucose levels**—fasting blood glucose level of 100 mg/dL or above, or taking medication for elevated blood glucose

In addition to type 2 diabetes, metabolic syndrome has been linked to the following health disorders:

- obesity
- CVD

- PCOS
- nonalcoholic fatty liver disease
- chronic kidney disease

However, not everyone with these disorders has insulin resistance, and some people may have insulin resistance without getting these disorders.

People who are obese or who have metabolic syndrome, insulin resistance, type 2 diabetes, or prediabetes often also have low-level inflammation throughout the body and blood clotting defects that increase the risk of developing blood clots in the arteries. These conditions contribute to increased risk for CVD.

*Similar definitions have been developed by the World Health Organization and the American Association of Clinical Endocrinologists.

²

Alberti KG, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation*. 2009;120:1640–1645.

How are insulin resistance and prediabetes diagnosed?

Health care providers use blood tests to determine whether a person has prediabetes, but they do not usually test specifically for insulin resistance. Insulin resistance can be assessed by measuring the level of insulin in the blood.

However, the test that most accurately measures insulin resistance, called the euglycemic clamp, is too costly and complicated to be used in most health care providers' offices. The clamp is a research tool used by scientists to learn more about glucose metabolism. Research has shown that if blood tests indicate prediabetes, insulin resistance most likely is present.

Blood Tests for Prediabetes

All blood tests involve drawing blood at a health care provider's office or commercial facility and sending the sample to a lab for analysis. Lab analysis of blood is needed to ensure test results are accurate. Glucose measuring devices used in a health care

provider's office, such as finger-stick devices, are not accurate enough for diagnosis but may be used as a quick indicator of high blood glucose.

Prediabetes can be detected with one of the following blood tests:

- the A1C test
- the fasting plasma glucose (FPG) test
- the oral glucose tolerance test (OGTT)

A1C test. Sometimes called hemoglobin A1c, HbA1c, or glycohemoglobin test, this test reflects average blood glucose levels over the past 3 months. This test is the most reliable test for prediabetes, but it is not as sensitive as the other tests. In some individuals, it may miss prediabetes that could be caught by glucose tests.

Although some health care providers can quickly measure A1C in their office, that type of measurement—called a point-of-care test—is not considered reliable for diagnosis. For diagnosis of prediabetes, the A1C test should be analyzed in a laboratory using a method that is certified by the NGSP.

The A1C test can be unreliable for diagnosing prediabetes in people with certain conditions that are known to interfere with the results. Interference should be suspected when A1C results seem very different from the results of a blood glucose test. People of African, Mediterranean, or Southeast Asian descent, or people with family members with sickle cell anemia or a thalassemia, are particularly at risk of interference. People in these groups may have a less common type of hemoglobin, known as a hemoglobin variant, that can interfere with some A1C tests.

An A1C of 5.7 to 6.4 percent indicates prediabetes.

Fasting plasma glucose test. This test measures blood glucose in people who have not eaten anything for at least 8 hours. This test is most reliable when done in the morning. Prediabetes found with this test is called IFG.

Fasting glucose levels of 100 to 125 mg/dL indicate prediabetes.

OGTT. This test measures blood glucose after people have not eaten for at least 8 hours and 2 hours after they drink a sweet liquid provided by a health care provider or laboratory. Prediabetes found with this test is called IGT.

A blood glucose level between 140 and 199 mg/dL indicates prediabetes.

The following table lists the blood test levels for a diagnosis of prediabetes.

	A1C (percent)	Fasting Plasma Glucose (mg/dL)	Oral Glucose Tolerance Test (mg/dL)
Diabetes	6.5 or above	126 or above	200 or above
Prediabetes	5.7 to 6.4	100 to 125	140 to 199
Normal	About 5	99 or below	139 or below

Source: Adapted from American Diabetes Association. Standards of medical care in diabetes—2012. *Diabetes Care*. 2012;35(Supp 1):S12, table 2.

Understanding Test Results

A blood test indicating prediabetes means that insulin resistance has progressed to the point where the beta cells in the pancreas can no longer compensate and a person's blood glucose levels are rising toward type 2 diabetes. The higher the test results, the greater the risk of type 2 diabetes. The level of risk also depends on an individual's other risk factors, which are listed in the section "[Who should be tested for prediabetes?](#)"

Test numbers. For example, people with an A1C below 5.7 percent may still be at risk for diabetes if they have a family history of type 2 diabetes or have gained excess weight around the waist. People with an A1C above 6.0 percent should be considered at very high risk of developing diabetes. A level of 6.5 percent or above means a person has diabetes.

Follow up. People whose test results indicate they have prediabetes may be retested in 1 year and should consider making lifestyle changes to reduce their risk of developing type 2 diabetes.

Varying results. Although all these tests can be used to test for prediabetes, in some people one test will indicate a diagnosis of prediabetes or diabetes when another test does not. People with differing test results may be in an early stage of the disease, where blood glucose levels have not risen high enough to show on every test.

Health care providers repeat laboratory tests to confirm test results. Diabetes develops over time, so even with variations in test results, health care providers can tell when overall blood glucose levels are becoming too high.

Can insulin resistance and prediabetes be reversed?

Yes. Physical activity and weight loss help the body respond better to insulin. The Diabetes Prevention Program (DPP) was a federally funded study of 3,234 people at high risk for diabetes.

The DPP and other large studies proved that people with prediabetes can often prevent or delay diabetes if they lose a modest amount of weight by cutting fat and calorie intake and increasing physical activity—for example, walking 30 minutes a day, 5 days a week.

People at High Risk for Diabetes

DPP study participants were overweight and had prediabetes. Many had family members with type 2 diabetes. Prediabetes, obesity, and a family history of diabetes are strong risk factors for type 2 diabetes. About half of the DPP participants were from minority groups with high rates of diabetes, including African Americans, Alaska Natives, American Indians, Asian Americans, Hispanics/Latinos, and Pacific Islander Americans.

DPP participants also included others at high risk for developing type 2 diabetes, such as women with a history of gestational diabetes and people ages 60 and older.

Approaches to Preventing Diabetes

The DPP tested three approaches to preventing diabetes:

- **Making lifestyle changes.** People in the lifestyle change group exercised, usually by walking 5 days a week for about 30 minutes a day, and lowered their intake of fat and calories.
- **Taking the diabetes medication metformin.** Those who took metformin also received information about physical activity and diet.
- **Receiving education about diabetes.** The third group only received information about physical activity and diet and took a placebo—a pill without medication in it.

People in the lifestyle change group showed the best outcomes. However people who took metformin also benefited. The results showed that by losing an average of 15 pounds in the first year of the study, people in the lifestyle change group reduced their risk of developing type 2 diabetes by 58 percent over 3 years.

Lifestyle change was even more effective in those ages 60 and older. People in this group reduced their risk by 71 percent.

People in the metformin group also benefited, reducing their risk by 31 percent. More information about the DPP, funded under NIH clinical trial number NCT00004992, is available at www.bsc.gwu.edu/dpp.

Lasting Results

The Diabetes Prevention Program Outcomes Study (DPPOS) has shown that the benefits of weight loss and metformin last for at least 10 years. The DPPOS has continued to follow most DPP participants since the DPP ended in 2001. The DPPOS showed that 10 years after enrolling in the DPP

- people in the lifestyle change group reduced their risk for developing diabetes by 34 percent

- those in the lifestyle change group ages 60 or older had even greater benefit, reducing their risk of developing diabetes by 49 percent
- participants in the lifestyle change group also had fewer heart and blood vessel disease risk factors, including lower blood pressure and triglyceride levels, even though they took fewer medications to control their heart disease risk
- those in the metformin group reduced their risk of developing diabetes by 18 percent

Even though controlling weight with lifestyle changes is challenging, it produces long-term health rewards by lowering the risk for type 2 diabetes, lowering blood glucose levels, and reducing other heart disease risk factors.

What steps can help reverse insulin resistance and prediabetes?

By losing weight and being more physically active, people can reverse insulin resistance and prediabetes, thus preventing or delaying type 2 diabetes. People can decrease their risk by

- eating a healthy diet and reaching and maintaining a healthy weight
- increasing physical activity
- not smoking
- taking medication

Eating, Diet, and Nutrition

Adopting healthy eating habits can help people lose a modest amount of weight and reverse insulin resistance. Experts encourage people to slowly adopt healthy eating habits that they can maintain, rather than trying extreme weight-loss solutions. People may need to get help from a dietitian or join a weight-loss program for support.

In general, people should lose weight by choosing healthy foods, controlling portions, eating less fat, and increasing physical activity. People are better able to lose weight and keep it off when they learn how to adapt their favorite foods to a healthy eating plan.

The DASH (Dietary Approaches to Stop Hypertension) eating plan, developed by the NIH, has been shown to be effective in decreasing insulin resistance when combined with weight loss and physical activity. More information on DASH is available at www.nhlbi.nih.gov/health/health-topics/topics/dash.

The U.S. Dietary Guidelines for Americans also offers healthy eating advice and tools for changing eating habits at www.choosemyplate.gov.

Dietary Supplements

Vitamin D studies show a link between people's ability to maintain healthy blood glucose levels and having enough vitamin D in their blood. However, studies to determine the proper vitamin D levels for preventing diabetes are ongoing; no special recommendations have been made about vitamin D levels or supplements for people with prediabetes.

Currently, the Institute of Medicine (IOM), the agency that recommends supplementation levels based on current science, provides the following guidelines for daily vitamin D intake:

- People ages 1 to 70 years may require 600 International Units (IUs).
- People ages 71 and older may require as much as 800 IUs.

The IOM also recommended that no more than 4,000 IUs of vitamin D be taken per day.

To help ensure coordinated and safe care, people should discuss use of complementary and alternative medicine practices, including the use of dietary supplements, with their health care provider.

More information about using dietary supplements to help with diabetes is available from the NDIC at www.diabetes.niddk.nih.gov/dm/pubs/alternativetherapies/index.aspx.

Physical Activity

Regular physical activity tackles several risk factors at once. Regular physical activity helps the body use insulin properly.

Regular physical activity also helps a person

- lose weight
- control blood glucose levels
- control blood pressure
- control cholesterol levels

People in the DPP who were physically active for 30 minutes a day, 5 days a week, reduced their risk of type 2 diabetes. Many chose brisk walking as their physical activity.

Most people should aim for at least 30 minutes of exercise most days of the week. For best results, people should do both aerobic activities, which use large muscle groups and make the heart beat faster, and muscle strengthening activities.

Aerobic activities include brisk walking, climbing stairs, swimming, dancing, and other activities that increase the heart rate.

Muscle strengthening activities include lifting weights and doing sit-ups or push-ups.

People who haven't been physically active recently should talk with their health care provider about which activities are best for them and have a checkup before starting an exercise program.

Not Smoking

Those who smoke should quit. A health care provider can help people find ways to quit smoking. Studies show that people who get help have a better chance of quitting.

For more information about how to reverse insulin resistance and prediabetes with diet and increased physical activity, see the following National Diabetes Education Program publications at www.yourdiabetesinfo.org:

- *Get Real! You Don't Have to Knock Yourself Out to Prevent Diabetes!*
- *More Than 50 Ways to Prevent Diabetes*
- *Small Steps. Big Rewards. Your Game Plan to Prevent Type 2 Diabetes.*

Medication

The medication metformin is recommended for treatment of some individuals at very high risk of developing type 2 diabetes. In the DPP, metformin was shown to be most effective in preventing or delaying the development of type 2 diabetes in younger, heavier people with prediabetes. In general, metformin is recommended for those who are younger than age 60 and have

- combined IGT and IFG
- A1C above 6 percent
- low HDL cholesterol
- elevated triglycerides
- a parent or sibling with diabetes
- a BMI of at least 35

Metformin also lowers the risk of diabetes in women who have had gestational diabetes. People at high risk should ask their health care provider if they should take metformin to prevent type 2 diabetes.

Several medications have been shown to reduce type 2 diabetes risk to varying degrees, but the only medication recommended by the ADA for type 2 diabetes prevention is metformin. Other medications that have delayed diabetes have side effects or haven't shown long-lasting benefits. No medication, including metformin, is approved by the U.S. Food and Drug Administration to treat insulin resistance or prediabetes or to prevent type 2 diabetes.

Points to Remember

- Insulin is a hormone that helps cells throughout the body absorb glucose and use it for energy. Insulin resistance is a condition in which the body produces insulin but does not use it effectively.
- Insulin resistance increases the risk of developing type 2 diabetes and prediabetes.
- The major contributors to insulin resistance are excess weight, especially around the waist, and physical inactivity.
- Prediabetes is a condition in which blood glucose or A1C levels—which reflect average blood glucose levels—are higher than normal but not high enough for a diagnosis of diabetes.
- The Diabetes Prevention Program (DPP) study and its follow-up study, the Diabetes Prevention Program Outcomes Study (DPPOS), confirmed that people with prediabetes can often prevent or delay diabetes if they lose a modest amount of weight by cutting fat and calorie intake and increasing physical activity.
- By losing weight and being more physically active, people can reverse insulin resistance and prediabetes, thus preventing or delaying type 2 diabetes.
- People with insulin resistance and prediabetes can decrease their risk for diabetes by eating a healthy diet and reaching and maintaining a healthy weight, increasing physical activity, not smoking, and taking medication.
- The DPP showed the diabetes medication metformin to be most effective in preventing or delaying the development of type 2 diabetes in younger and heavier people with prediabetes and women who have had gestational diabetes.

Hope through Research

The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) conducts and supports research in insulin resistance, diabetes, glucose metabolism, and related conditions. Clinical trials related to diabetes include

- Genetic Studies of Insulin and Diabetes, funded by the NIDDK under NIH clinical trial number NCT00001987
- Diabetes and Heart Disease Risk in Blacks, funded by the NIDDK under NIH clinical trial number NCT00001853

Clinical trials are research studies involving people. Clinical trials look at safe and effective new ways to prevent, detect, or treat disease. Researchers also use clinical trials to look at other aspects of care, such as improving the quality of life for people with chronic illnesses. To learn more about clinical trials, why they matter, and how to participate, visit the NIH Clinical Research Trials and You website at www.nih.gov/health/clinicaltrials. For information about current studies, visit www.ClinicalTrials.gov.

For more information about the NIDDK's research on diabetes and related topics, see www.diabetes.niddk.nih.gov/diabetesresearch/dm_research.aspx.

For More Information

American Association of Diabetes Educators

200 West Madison Street, Suite 800

Chicago, IL 60606

Phone: 1-800-338-3633

Internet: www.diabeteseducator.org 

American Diabetes Association

1701 North Beauregard Street

Alexandria, VA 22311

Phone: 1-800-DIABETES (1-800-342-2383)

Email: askADA@diabetes.org

Internet: www.diabetes.org 

National Heart, Lung, and Blood Institute Health Information Center

Attn: Website

P.O. Box 30105

Bethesda, MD 20824–0105

Phone: 301–592–8573

Telecommunications Relay Services: 7-1-1

Fax: 301-592-8563

Email: nhlbiinfo@nhlbi.nih.gov

Internet: www.nhlbi.nih.gov

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You may also find additional information about this topic by visiting MedlinePlus at www.medlineplus.gov.

This publication may contain information about medications and, when taken as prescribed, the conditions they treat. When prepared, this publication included the most current information available. For updates or for questions about any medications, contact the U.S. Food and Drug Administration toll-free at 1–888–INFO–FDA (1–888–463–6332) or visit www.fda.gov. Consult your health care provider for more information.

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National Diabetes Education Program

1 Diabetes Way

Bethesda, MD 20814–9692

Phone: 1–888–693–NDEP (1–888–693–6337)

TTY: 1–866–569–1162

Fax: 703–738–4929

Email: ndep@mail.nih.gov

Internet: www.ndep.nih.gov

www.yourdiabetesinfo.org

The National Diabetes Education Program is a federally funded program sponsored by the U.S. Department of Health and Human Services' National Institutes of Health and the Centers for Disease Control and Prevention and includes over 200 partners at the federal, state, and local levels, working together to reduce the morbidity and mortality associated with diabetes.

National Diabetes Information Clearinghouse

1 Information Way

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Email: ndic@info.niddk.nih.gov

Internet: www.diabetes.niddk.nih.gov

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Established in 1978, the Clearinghouse provides information about diabetes to people with diabetes and to their families, health care professionals, and the public. The NDIC answers inquiries, develops and distributes publications, and works closely with professional and patient organizations and Government agencies to coordinate resources about diabetes.

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