Introduction
Regular physical activity has the potential to yield several health benefits for people with diabetes. These benefits can include improvements in blood glucose control, insulin sensitivity, blood lipid profiles, blood pressure, coagulation properties, body composition and psychological well-being. Furthermore, most people with diabetes can derive benefits from regular activity, whether they are novice, a seasoned exerciser or are experiencing diabetes related complications.

When chronic complications of diabetes develop, careful consideration of the benefits and risks of exercise will maximize the benefits and assure safety. Attention must also be given to the effects of not participating in some level of physical activity. This phenomenon is known as Disuse Syndrome, the deleterious effect of an imbalance between rest and physical activity. Its effects may include decreased physical work capacity (the ability to do the activities of daily living), muscle atrophy, negative nitrogen and protein balance, cardiovascular de-conditioning, pulmonary restrictions and depression. The consequences of this Syndrome, in addition to the complications of diabetes, are likely to lead to even greater disability than that caused by complications of diabetes alone. Since physical activity can prevent or reverse Disuse Syndrome, serious consideration must be given to the use of exercise in all people with diabetes including those with complications. An appropriate physical activity prescription may also aid in the management of specific diabetes related complications.

This article provides the diabetes health care team some insights into the role of exercise and the safe and appropriate prescription thereof for this high-risk patient population. With the correct screening, a variety of safe exercises is possible. A detailed pre-participation screening and physical examination is thus always required prior to participation in all activities.
Comprehensive pre-activity screening

Red flags

In all cases, a comprehensive case history must be taken to establish if any red flags (absolute contraindications) exist for a chosen activity. If the individual has a history of cardiovascular disease, autonomic neuropathy, peripheral neuropathy with ulcerations, proliferative retinopathy or end stage nephropathy, they would require written clearance from their medical practitioner to participate in specific activities.

Common diabetes complications and appropriate exercise recommendations:

1) Diabetic Autonomic Neuropathy (DAN)

Diabetic autonomic neuropathy typically involves many organ systems (e.g. cardiovascular, respiratory, neuro-endocrine, gastrointestinal, genitourinary and ocular). Since the autonomic nervous system regulates all involuntary functions in the body, many of these systems are integral to the ability to perform exercise.

Effects of Autonomic Neuropathy on exercise response

The impact of autonomic neuropathy on the cardiovascular system is of utmost importance to exercise capacity and safety, since Cardiovascular Autonomic Neuropathy (CAN) manifests as abnormalities in heart rate and blood pressure and a redistribution of blood flow.

Blood pressure with cardiovascular autonomic neuropathy (CAN)

Blood pressure response with posture change and during exercise is abnormal in individuals with CAN. Postural hypotension upon standing is often observed. The symptoms of hypotension may also occur with eating or within a few minutes of taking insulin. This effect of insulin may be the result of direct action of insulin on the peripheral blood vessels resulting in vasodilatation. Insulin-induced hypotension is often worse in the morning and improves later in the day. This must be considered when determining the timing of exercise in relation to meals and insulin injections. Exercise may need to be deferred to later in the day and insulin should not be injected just before exercise.

Symptoms of postural hypotension may be similar to those of hypoglycaemia and may be mistaken for a drop in blood glucose. Individuals should be alerted to the potential confusion in interpreting any sensation of light-headedness or dizziness as hypoglycaemia and rather to test their glucose levels and act accordingly. Orthostatic hypotension is diagnosed by a fall in systolic blood pressure of at least 20 mmHg and a fall in diastolic blood pressure of at least 10 mmHg when a person assumes a standing position.

Exercise prescription for people with established cardiovascular autonomic neuropathy

De-conditioning from lack of exercise exacerbates orthostatic hypotension. Mild physical exercise improves orthostatic tolerance by reducing venous pooling and increasing plasma volume. Because upright exercise may increase orthostatic drops in blood pressure, training in a supine or sitting position is advisable. Swimming and other water activities and stationary and semi-recumbent cycling are especially beneficial. In addition, sitting in a chair doing light resistance exercises (e.g. lifting light weights or using an elastic exercise band) may help maintain or increase muscle strength.

Activities that should be avoided are those that cause rapid changes in body position (e.g. aerobics or kickboxing) or exercises that cause rapid and significant changes in heart rate and blood pressure (e.g. high-intensity running or lifting heavy weights).

Duration and intensity

The duration of exercise in those people with cardiovascular autonomic neuropathy should be determined by the person’s exercise tolerance. The starting duration should be based on the results of the exercise screening that was conducted before initiation of the exercise programme and may be just a few minutes. The intensity of the exercise should not be increased to compensate for shortened exercise sessions.

In most cardiovascular-type exercise prescriptions, it is frequently recommended that heart rate be used to determine the intensity of exercise. However, in individuals with CAN, heart rate is not an appropriate indicator of intensity, since maximal heart rate is not readily calculable. Instead, careful attention should be given to a person’s subjective feelings of intensity using the Rating of Perceived Exertion (RPE) scale (Table 1).

Table I: Rating of Perceived Exertion (RPE) Scale

<table>
<thead>
<tr>
<th>RPE</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
</tr>
<tr>
<td>0.5</td>
<td>Very, very weak</td>
</tr>
<tr>
<td>1</td>
<td>Very weak</td>
</tr>
<tr>
<td>2</td>
<td>Weak</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat strong</td>
</tr>
<tr>
<td>5</td>
<td>Strong</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very strong</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Very, very strong / Maximal</td>
</tr>
</tbody>
</table>
Exercise intensity is prescribed according to the numerical values associated with corresponding adjectives, subjectively describing intensity. People with complications of diabetes should strive to reach a moderate-range RPE (−3) gradually over 2–4 weeks. It is important that health care professionals clearly explain the RPE scale and emphasize its reliance on subjective feelings. Exercise should be terminated if a person reaches an RPE of 7 or above or is unable to talk.

**Abnormal Neuroendocrine Response**
People with autonomic neuropathy may display a blunted response to exercise by catecholamines and other gluco-regulatory hormones. This enhances the risk for hypoglycaemia both during and after activity and may be a contributing factor to exercise intolerance. The importance of self-monitoring of blood glucose (SMBG) cannot be overemphasized, since the metabolic response to exercise may be highly variable in these individuals.

**Gastroparesis**
Gastroparesis may be present in some people with autonomic neuropathy. The effect of gastroparesis on exercise capacity is related to timing of the arrival of nutrients to the bloodstream. It is important that people are aware of their specific presentation of gastroparesis and timing of nutrient delivery. Liquids are preferred over solids to prevent or treat hypoglycaemia, since the rate of liquid emptying remains within the normal range in most cases. A mismatch between insulin levels and blood glucose may be especially common. Exercise should be planned around gastric delivery of nutrients to try to counteract its acute glucose-lowering effects.

**Hypoglycaemia Unawareness**
The loss of early warning signs of hypoglycaemia can occur in people with autonomic neuropathy. It is vital for people with hypoglycaemia unawareness to frequently check their blood glucose to identify otherwise asymptomatic hypoglycaemia and thus prevent the deleterious effects of this. Frequent monitoring of blood glucose is especially important during and after physical activity, since reductions in blood glucose can occur during and up to several hours after exercise.

Due to the risk of hypoglycaemia unawareness in people with autonomic neuropathy, individuals should receive careful instruction about the frequency and timing of self-blood glucose monitoring, insulin action (onset, peak and duration) and the importance of trying to avoid exercise at the peak insulin action, or before the stomach has delivered its contents (if gastroparesis is also present). Individuals should be instructed on how to prevent and treat hypoglycaemia and family members, friends and colleagues likely to be present during and after exercise, should be trained in the use of glucagon. A set time for participating in physical activity may be useful in reducing the adjustments needed to minimise glycaemic excursions.

**Exercise Capacity and Evaluation for the Presence of Coronary Artery Disease (CAD)**
In addition to evaluating the individual for the presence and severity of autonomic neuropathy, testing should be conducted to determine exercise capacity and whether coronary artery disease (CAD) is present. Exercise testing protocols for populations at risk for CAD are recommended for those who meet any of the following criteria:

- type 1 diabetes and >35 years of age;
- type 2 diabetes and >35 years of age;
- type 1 diabetes for >15 years;
- presence of any microvascular or neurological complications of diabetes;
- presence of one or more additional coronary risk factors.

Non-invasive testing such as the stress / treadmill electrocardiogram (ECG) can assist in detecting asymptomatic CAD. However, effort testing alone will not completely identity all underlying CAD and those patients with CAD may thus require additional diagnostic testing under the supervision of a cardiologist.

**Exercise prescription for people with coronary artery disease**
In most cases, it is recommended that people with type 1 or type 2 diabetes perform an equal combination of endurance and resistance type exercise. However, with a cardiac history, it is recommended that 70% of the workout should be in the form of endurance type activities.

**Exercises that may be unsafe for people with established coronary artery disease**
Exercises above the head such as shoulder presses, exercises that induce the Valsalva manoeuvre, or aerobic exercise at a heart rate maximum above 80% for a prolonged period, may be unsafe for people with cardiovascular disease. These types of exercise may raise a person’s rate pressure product (RPP) and place excessive stress on diseased vessels. Rate pressure product is a
measure of the stress put on the cardiac muscle based on the number of times it needs to beat per minute (HR) and the arterial blood pressure that it is pumping against (SBP). It will be a direct indication of the energy demand on the heart and is thus a good measure of its energy consumption. RPP is used in cardiology and exercise physiology to determine the cardiovascular risk of subjects.

2) Peripheral Neuropathy
 Peripheral neuropathy of the sensory nerves presents clinically as tingling, pain or loss of sensation in the toes and feet. Common symptoms associated with motor nerve damage are muscle weakness, cramps and spasms. Both sensory and motor nerve damage increase the risk of balance and gait disturbances and a subsequent increase in fall risk. If an individual has a history of peripheral neuropathy and foot ulcers, the risk of developing further ulcers with walking or jogging is high. We would recommend that the person acquire medical clearance from their Specialist or Podiatrist before participating in any weight-bearing activity.

Sweating and cutaneous blood flow disturbances in the lower limbs
 In addition to peripheral neuropathy, reduced or absent sweating in the lower limbs and hyperhydrosis of the upper half of the body may be present in autonomic neuropathy. The loss of sweating in the lower limbs can cause dry, brittle skin on the feet, which can contribute to ulcer formation. In addition, microvascular blood flow to the skin is impaired in individuals with autonomic neuropathy. This causes a poor response to vasoconstrictors (such as cold) and vasodilators (such as heat). Both sweating disturbances and compromised cutaneous blood flow in the lower limbs emphasize the ongoing need to provide appropriate foot care education before the commencement of an exercise programme.

Suggested exercise prescription for peripheral neuropathy
 Incorporating balance/proprioceptive type exercises such as the stork stand and standing on a wobble board or AIREX® BeBalanced® Balance-pad may be useful. Walking with one foot directly in front of the other teaches people balance and proprioception. Avoid repetitive weight-bearing activities such as walking or jogging for more than 10 minutes at a time. It is also extremely important that individuals stay adequately hydrated and avoid exercise in extreme temperatures.

A suitable choice of controlled, low-moderate intensity exercises are those in a gym circuit that can be performed in a seated position. Alternately one could cycle on a stationary cycle, row on a rowing ergometer or swim. However, if a person has a foot ulcer, the feet should be kept clean and dry and swimming should be avoided.

3) Proliferative Retinopathy
 Any exercise that increases blood pressure should be avoided. For people who have active proliferative diabetic retinopathy (PDR), strenuous activity may precipitate vitreous haemorrhage or traction retinal detachment. Strict avoidance of lifting heavy objects, inducing the Valsalva Manoeuvre and any vigorous exercise, which raises the heart rate, is mandated. Other examples of exercises that can increase the pressure on the retina and exacerbate vision loss include those that jar the head and eyes, such as bending forward in yoga, football, hockey or basketball.

Exercise prescription
 Non-weight bearing exercise such as light-moderate intensity cycling, or walking in the pool may be preferable for people with PDR. Slow, steady walking and low-intensity ballroom dancing may also be suitable.
4) **Nephropathy**
Specific physical activity recommendations have not been developed for individuals with nephropathy. Patients with nephropathy often have multi-factorial reasons for reduced physical activity capacity. These can include fluid fluxes, anaemia and electrolyte derangements.

Although there is no clear reason to limit low- to moderate-intensity forms of activity, high-intensity or strenuous physical activity should probably be discouraged in these individuals, unless blood pressure and fluid intake are carefully monitored during exercise.

**Exercise prescription:**
Light to moderate intensity exercise such as walking, cycling on stationary bike or low-moderate intensity exercise on a gym circuit should be recommended. Each exercise session should not last longer than 20-30 minutes.

**General Exercise advice for all individuals with diabetes complications**
In addition to the type and intensity of the exercise prescribed, frequency and rate of progression of the physical activity should be discussed. Individuals with complications must be given information on safety precautions and symptoms to be aware of if discernible ones do develop. It may be most appropriate for those with CAN to participate in exercise programmes supervised by people trained in cardiac care and with an adequate understanding of diabetes. Biokineticists trained in cardiac rehabilitation are well positioned in this regard.

**Type of exercise**
A person’s interest level and safety of the chosen exercise should primarily drive the type of activity selected.

**Frequency and duration**
Physical activity should be performed on most, if not all, days of the week to obtain health-related benefits. For those people with complications of diabetes, this recommendation has added significance.

The intensity and duration of physical activity may be modest in many of these individuals. If even a small amount of physical activity is performed each day, some benefit will be derived with minimal risk. It is more likely the activity will become a habit if participation occurs on a daily basis. Daily activity will also reduce the difficulty of balancing insulin dosages and food intake with physical activity.

**Rate of Progression**
Progression of exercise in those with complications of diabetes should be done cautiously. **Emphasis should be placed on increasing the frequency first (if exercise is not yet being done daily) and then the duration of activity before finally increasing the intensity.** The duration of physical activity should be gradually increased to accommodate the person’s functional capacity and clinical status. Any increase in intensity should be small and approached cautiously to minimize the risk of any dangerous cardiovascular events or musculoskeletal injuries. Since those with CAN have a higher incidence of abnormal ventricular response to exercise, it is especially important to advance the exercise programme slowly and with cautious monitoring.

Other factors that may assist people in maintaining a physical activity programme include the following:
1. **Taking measures to avoid injury:** A warm-up and cool-down consisting of low-intensity activity and static stretches should be done to reduce the likelihood of injury.
2. **Setting well-defined exercise goals:** The goals should be precisely defined by exercise behaviour (e.g. walk for 10 minutes daily at a 2 RPE rating) rather than by a “hoped-for” outcome (e.g. reduction in HbA1c by 1 %).
3. **Setting an exercise schedule in advance:** Having a schedule can help both in terms of forming a habit of physical activity and in easier adjustment to the diabetes management plan.
4. **Involving an exercise partner:** An exercise partner can help with motivation and encouragement, as well as provide safety for a person with chronic complications. As mentioned above, a monitored exercise programme may be best for individuals with CAN.

**Conclusion**
Physical activity should be carefully considered for all people with diabetes. When chronic complications of diabetes develop, it is vital to weigh up the risks and benefits of an exercise programme in formulating an exercise prescription. The deleterious effects of not participating in any physical activity must also be considered when making decisions about the use of exercise in this population of patients.

To maximize the benefits of physical activity, it is imperative that exercise prescriptions are tailored to an individual’s set of circumstances (e.g. extent of complication involvement, medications, interest level, and desired outcomes of the exercise programme). The health care team together with the person with diabetes must develop exercise prescriptions jointly. The increased sense of well-being that results from regular physical activity is also an extremely important and often overlooked benefit for this population.