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Comprehensive Cardiovascular Risk Reduction and Cardiac Rehabilitation in Diabetes and the Metabolic Syndrome

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Abstract

The epidemic of obesity has contributed to a growing burden of metabolic syndrome (MetS) and diabetes mellitus (DM) worldwide. MetS is defined as central obesity along with associated factors such as hypertriglyceridemia, low high-density lipoprotein cholesterol, hyperglycemia, and hypertension. MetS and DM are associated with significant cardiovascular morbidity and mortality. Healthy behavioural modification is the cornerstone for reducing the atherosclerotic cardiovascular disease burden in this population. Comprehensive, multi-disciplinary cardiac rehabilitation (CR) programs reduce mortality and hospitalizations in patients with MetS and DM. Despite this benefit, patients with MetS and DM are less likely to attend and complete CR because of numerous barriers. Implementation of innovative CR delivery models might improve utilization of CR and cardiovascular outcomes in this high-risk population.

Abstract

L'épidémie d'obésité a contribué au fardeau croissant du syndrome métabolique (SMét) et du diabète dans le monde entier. Le SMét est défini par la présence de l'obésité abdominale ainsi que des facteurs qui y sont associés tels que l'hypertriglycéridémie, le faible taux de cholestérol à lipoprotéines de haute densité, l'hyperglycémie et l'hypertension. Le SMét et le diabète sont associés à une morbidité et une mortalité cardiovasculaires significatives. La modification des comportements en matière de santé est la pierre angulaire de la réduction du fardeau de la maladie cardiovasculaire athérosclérotique dans cette population. Les programmes multidisciplinaires exhaustifs de réadaptation cardiaque (RC) réduisent la mortalité et les hospitalisations chez les patients atteints du SMét et du diabète. En dépit de ces avantages, les patients atteints du SMét et du diabète sont moins susceptibles de participer et de compléter la RC en raison des nombreux obstacles. La mise en œuvre de modèles novateurs de prestation de programmes de RC améliorerait la participation à la RC et les issues cardiovasculaires de cette population à risque élevé.

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Cardiovascular (CV) disease (CVD) is the leading cause of mortality worldwide.[1] An epidemic of obesity has contributed to an increasing prevalence of CVD risk factors such as metabolic syndrome (MetS) and diabetes mellitus (DM). MetS is defined as a clustering of interrelated metabolic factors that together represent a multiplex CV risk factor.[2] According to the harmonized definition, MetS is classified as central obesity (see Table 1 for criteria) with associated factors such as hypertriglyceridemia, low high-density lipoprotein cholesterol (HDL-C), hyperglycemia, and hypertension (Table 2).[3] Waist circumference thresholds for abdominal obesity have been shown to vary according to region and ethnicity. The International Diabetes Foundation (IDF) defines this similarly with 2 important exceptions: that (1) abdominal obesity is central to MetS; and thus, (2) abdominal obesity plus 2 of the other remaining 4 criteria must be met. Additionally, because of the variations in waist measurements, the IDF has developed alternative waist circumference thresholds for defining abdominal obesity (Table 1). Multiple landmark trials have used obesity cut points from the National Cholesterol Education Program and IDF for the MetS. The IDF criteria were found to be slightly more sensitive for the diagnosis of MetS (13.3% vs 10.4%) than the National Cholesterol Education Program criteria in a head-to-head comparison.[4]

The prevalence of obesity and associated MetS has increased to epidemic proportions globally. According to the World Health Organization (WHO), the rate of obesity has doubled since 1980, with 600 million people, or 13% of the global population, meeting criteria for obesity.[5] A similar trend is observed in the Canadian population. Results from the Canadian Community Health Survey from 2010 to 2014 show that the prevalence of obesity has increased from 38.1% to 40%.[6,7] The relationship between obesity and MetS was illustrated in the **N**ational **H**ealth **a**nd **N**utritional **E**xamination **S**urvey (NHANES) III study, which identified the presence of MetS in 5% of normal weight, 22% of overweight, and 60% of obese individuals.[9] This is largely attributed to an increase in poor nutrition, sedentary health behaviours, and the relative aging of populations.[10] MetS affected approximately 22.9% of adults (20 years of age and older) in the United States in 2010 and 25.5% of the overall population in 1999.[11] This favourable trend is attributed to a decrease in hypertriglyceridemia and hypertension because of improved medical management, despite waist circumference and hyperglycemia becoming increasingly widespread over the same period of time.[11] Despite this encouraging trend, MetS remains a significant cause of morbidity and mortality worldwide.

Socioeconomic status has been shown to have an influence on one's likelihood of being diagnosed with MetS in Canada.[12,13] Along with MetS, the prevalence of DM continues to increase in epidemic proportions. Thirty million people worldwide were estimated to have DM in 1985, and this figure is projected to approach 350 million by 2050.[14] As of 2009, there were 2.4 million people (6.8%) with DM living in Canada, with 7.2% of men and 6.4% of Canadian women having DM.[15] The Canadian Diabetes Association has estimated that the 2015 prevalence of DM in Canada had climbed to 9.3% of the population and would continue to climb to 12.1% by the year 2025.[16]

Complications and Consequences

Consequences of obesity

Excess adiposity and obesity are associated with the development of MetS and DM. Body mass index (BMI) is a population-based estimate of body fat, and higher BMIs are associated with a greater incidence of diseases related to obesity. An individual with a BMI of 26 compared with another with a BMI of < 21 has a twofold increased risk of coronary artery disease (CAD) among women and a 1.5-fold increase among men. The association between BMI and DM is even more profound, with a fourfold increased risk of developing DM among men with a BMI of 26 and an eightfold risk in women of the same BMI.[17]

BMI is frequently used in epidemiologic studies because of its simplicity and convenience. There are, however, several limitations in using BMI as an assessment for body fat and CV risk such as the inability to differentiate fat mass from lean mass.[17] The distribution of body fat is another CV risk factor not adequately measured using BMI alone. Visceral adipose tissue disproportionately affects metabolic risk but is indistinguishable from subcutaneous adipose tissue using BMI.[18] Visceral adipose tissue is associated with increased bio-markers of insulin resistance, dyslipidemia, and inflammation. Visceral adiposity causes many pathological metabolic changes, including increasing systemic levels of cytokines, increasing the liver's resistance to endogenous insulin, reducing HDL-C levels, and reducing the ability of the liver to synthesize very low-density lipoprotein.[19] These abnormal forms of lipid storage can result in risks similar to those of excessive lipid production or storage.[20] In contrast, subcutaneous adipose tissue has a more benign phenotype, which is less associated with dyslipidemia or atherosclerosis.[18] Because of these findings, measures of fat distribution, such as waist circumference and waist-to-hip ratio, are more specific to identify risk.[3,18]

Although excess body fat is an accepted risk factor for CVD, the mechanisms driving this association are still under investigation. Adipose tissue is actively involved in lipid storage but also functions as a metabolically-regulated endocrine organ.[21,22] Fat secretes cytokines and other proteins, collectively called adipokines, the dysregulation of which is theorized to contribute to a proinflammatory state.[21]

Excessive fat increases an individual's production of inflammatory proteins including interleukin (IL)-6, tumour necrosis factor-α, leptin, resisten, angiotensinogen, and C-reactive protein (CRP), leading to a chronic low-grade inflammatory state that directly promotes atherogenesis. Adipokines also regulate other processes known to contribute to atherosclerosis, such as insulin resistance, hypertension, and endothelial dysfunction.[21,22] Tumour necrosis factor-α, for example, is an adipokine that directly upregulates inflammatory changes in the vascular tissue, promoting insulin resistance through inhibition of the insulin receptor signalling pathway.[21,22]

Complications of the MetS

MetS adversely affects CV outcomes through a combination of atherogenic dyslipidemia and dysglycemia. These factors result from the proinflammatory state associated with obesity, hypertension, and a prothrombotic state.[23,24] Individuals with at least 4 of 5 features

of MetS (Table 1) have a 3.7-fold increased risk of CAD at 5-year follow-up.[25] Long-term follow-up of individuals who met at least 3 criteria for MetS were reported to have a 4.2 times higher incidence of CAD.[26] A study of adults in the United States reported an increased adjusted risk of heart disease mortality (HR 2.02, CI 1.42-2.89), CVD mortality (HR 1.82, CI 1.40-2.37), and all-cause mortality (hazard ratio [HR], 1.40; 95% confidence interval [CI], 1.19-1.66) in individuals with MetS compared with those without MetS.[27] Importantly, the increased risk of mortality persisted in those with MetS, even in the absence of established DM.[27] A similar study of elderly subjects (aged 65-74 years) without DM reported increased coronary heart disease (CHD; HR, 1.58; 95% CI, 1.14-2.18), CVD (HR, 1.51; 95% CI, 1.17-1.93), and all-cause (HR, 1.21; 95% CI, 1.01-1.46) mortality in individuals with MetS, as defined by WHO criteria, after adjustment for age, sex, history of myocardial infarction (MI) and stroke, current smoking, alcohol consumption, leisure physical activity, and total cholesterol.[28] Furthermore, MetS also increases the adjusted risk for incident fatal or nonfatal stroke (HR, 1.57; 95% CI, 1.12-2.19) in nondiabetic individuals during a 14-year follow-up.[29]

Complications of DM

The effect of DM on CVD is well established. Eighty percent of individuals with DM will have a significant adverse cardiac event that will lead to their death, compared with 30% of the nondiabetic population.[30] Diabetic individuals, adjusted for population age differences, have a relative risk of 1.7 for CV death, 1.8 for hospitalization because of MI, and are 1.5 times more likely to suffer a stroke.[5,31–33] More importantly, DM confers the highest lifetime risk (67% in men and 57% in women) of any risk factor for developing CHD, and diabetic individuals are at the highest risk for macrovascular complications.[34] This association is further compounded by the fact that metabolic risk factors for atherosclerotic CVD (ASCVD) are commonly found in individuals with DM.[35]

The chronic complications of DM affect a variety of organ systems and are responsible for most related morbidity and mortality of the disease. Chronic complications of DM can be divided into vascular and nonvascular, with risk of complications for both increasing with degree and duration of hyperglycemia.[8] Vascular complications can be further subdivided into micro- and macrovascular complications. Microvascular complications include retinopathy and macular edema, neuropathy, and diabetic nephropathy.[36] Macro-vascular complications include CAD, cerebrovascular disease, and peripheral vascular disease.[31]

Population Health

Health promotion and disease prevention have increasingly been recognized as an important intervention to address the growing global ASCVD burden. A number of major organizations have launched initiatives focused on reducing the burden of CVD. Among these efforts is the American Heart Association (AHA) 2020 Impact Goal, which prioritizes improving CV health by 20% and decreasing mortality from CV disease and stroke by 20% by the year 2020.[37] This would be accomplished by increasing awareness and counselling on risk factors such as tobacco abuse, obesity, poor nutrition, hypertension, hyperlipidemia, and disordered glucose metabolism. Similarly, the “25by25” initiative by the WHO is a

global effort with the stated goal of decreasing premature mortality from CV events, stroke, and DM by 25% by the year 2025. The Public Health Agency of Canada has a similar initiative with the Canadian Diabetes Strategy, which focuses on increased surveillance, public education, and community-based programs.[15]

Because of the increasing prevalence of obesity and MetS, a cardiometabolic think tank convened in June 2014 with a focus on defining and implementing new patient care models to best manage patients with CV risk factors and MetS.[38] This consortium created an integrated care model focused on prevention and disease management, which among other changes in care delivery, included a shift in care from the clinic to the community.[38]

This care model defines subtypes of MetS, including vascular dominant, lipid dominant, insulin resistant dominant, and adiposity dominant, allowing clinicians to appreciate the substantial variability in end organ consequences with differing management schemes. The model includes a staging system of MetS that ranges from at risk (stage A) to evidence of end organ damage (stage D). These changes signify the heterogeneity of the disease and highlight the need for more specific and evidence-based management algorithms.[38]

With the promise of emerging technology in health care comes the issue of our increasing dependency on technology and its complicated role in the obesity epidemic. At present, much of our transportation infrastructure is centred on the automobile. Environmental engineering-based public health initiatives, such as constructing cyclist-friendly roadways and increasing green space, can be important interventions. According to a 2010 report from the US Centers for Disease Control and Prevention, only 50% of individuals 18 years of age and older were achieving federal guidelines for physical activity, with this number decreasing to 30% for individuals older than the age of 75 years.[39] Positive changes at a legislative level, such as mandatory calorie labelling in restaurants and banning hydrogenated fats, can help decrease the burden of CV morbidity and mortality.[40,41] These population health initiatives are important efforts to reduce the global burden of CVD.

Healthy Behaviour Management

Healthy behavioural modification, specifically focused on diet and exercise, remains a cornerstone for reducing the risk of MetS, DM, and ASCVD.[38] The American College of Cardiology and AHA Lifestyle Workgroup published guidelines on behavioural management focused on reducing CV risk in 2013.[42]

Dietary modification

There is strong evidence that shows that low-density lipo-protein cholesterol (LDL-C) and blood pressure reduction is achieved with a dietary pattern that emphasizes vegetables, fruits, whole grains, low-fat dairy, fish, poultry, legumes, and nontropical vegetable oils. These dietary patterns are best achieved with approaches such as Dietary Approaches to Stop Hypertension, AHA Diet, and US Department of Agriculture Food Pattern.[42,43] Several trials involving patients with MetS provided a head-to-head comparison, showing the superiority of the Mediterranean-style diet (MedSD) over low-carbohydrate and low-fat diets for reducing the risk of developing CVD.[44–47]

The MedSD has also shown benefit in reducing CV risk.[48,49] Similar to other heart-healthy dietary patterns, this approach emphasizes whole grains, fresh fruit, vegetables, legumes, and nuts, in addition to limiting consumption of red meat. Other distinctive features are moderate consumption of wine and fatty fish, such as salmon and mackerel, which are rich in omega-3 fatty acids. Extra virgin olive oil is another staple of Mediterranean cuisine and is the primary source of added fat in these diets.[42,48]

The MedSD is associated with risk reduction for ASCVD and MetS and is effective for prevention of CVD.[48] In the **Pre**vención con **Di**eta **Med**iterránea (PREDIMED) trial, participants assigned a MedSD had a 30% reduction in major CV events compared with the low-fat control group.[50] Subsequent analyses of PREDIMED have supported previous observational studies[51,52] and randomized controlled trials and have concluded that the MedSD promotes metabolic improvement in DM and MetS.[53] Similar results were seen in a meta-analysis of 50 studies representing 523,906 subjects. The Lyon Diet Heart Study showed that starting MedSD after having an MI was associated with a decreased risk of recurrent MI and cardiac death by 72% at 4 years.[54] Other objective measures of health also improve with a MedSD, including a decrease in waist circumference, systolic blood pressure, diastolic blood pressure, and glucose by 0.42 cm, 2.35 mm Hg, 1.35 mm Hg, and 3.89 mg/dL, respectively, and an increase in HDL-C by 1.17 mg/dL.[49] Such positive dietary changes also reduce serum concentrations of proinflammatory proteins including CRP, IL-6, and IL-8.[55]

Physical activity

Physical activity is another important component of a heart-healthy life. Regular physical activity is associated with an antiatherogenic, anti-inflammatory, anti-ischemic, and antiarrhythmic effect along with an improvement in ASCVD risk factors.[56,57] The AHA/American College of Cardiology Lifestyle Workgroup advises adults to engage in 40 minutes of moderate to vigorous aerobic activity 3-4 times per week.[42] This regimen decreased LDL-C by 3-6 mg/dL and systolic and diastolic blood pressure by 2-5 mm Hg and 1-4 mm Hg, respectively.[42]

Regular aerobic exercise also improves individual risk factors related to the MetS.[58] In the **S**tudies **T**argeting **R**isk **R**eduction **I**nterventions through **D**efined **E**xercise (STRRIDE) trial, 334 subjects were randomized into 1 of 3 eight-month exercise programs. All 3 interventions prevented accumulation of visceral fat and participants had statistically significant reductions in waist size.[59] Surprisingly, after analyzing the intensity of exercise across intervention groups, the trial showed that low-intensity exercise might actually be superior for metabolic health.[58] In addition, those who engaged in assigned aerobic activity had a 52% improvement in insulin sensitivity, which was sustained for as many as 14 days after the most recent aerobic activity session.[60]

Comprehensive CVD risk factor control remains suboptimal in diabetic individuals. A study by Wong et al. showed that despite an approximate 50% of diabetic patients being at goal for either hemoglobin (Hgb) A1c, blood pressure, or LDL-C, only 24% of these patients were at goal for all 3 risk factors.[61] The STENO-2 study showed that targeted and intensive multifactorial intervention reduces the development of CVD by 20%.[62] Systolic and

diastolic blood pressures were lower by 11 and 4 mm Hg, respectively, in the intensive intervention cohort. Fasting glucose control improved with an average reduction of 34 mg/dL and reduction in Hgb A1c by 0.5% in the intensive group. LDL-C was reduced by an average of 34 mg/dL. STENO-2 was able to provide a real world setting in which multiple parameters of risk reduction were discussed during patient encounters. Intensive pharmacologic therapy, including antihypertensive and antilipid medications, and biguanides vs thiazolidinedione were also readily initiated in these patients. This set the stage for various guidelines in the form of risk factor targets for disease. Albeit, these are moving targets at present, and we have yet to determine the optimal levels of systolic blood pressure and Hgb A1c targets for those with DM.[63] The investigators of the STENO trial concluded that only 5 patients would need to be treated intensively for an 8-year period to prevent 1 major CV event.

In the **Look A**ction for **Hea**lth in **D**iabetes (Look AHEAD) trial, patients who underwent intensive behavioural intervention had a significant reduction in weight (8.6% mean weight loss), Hgb A1c (mean 6.6% to 7.3%), waist circumference, and several other CV risk factors including blood pressure compared with overweight and obese diabetic participants who underwent DM-related education alone.[64] The study was halted after a 9.6-year follow-up because there was no significant difference in the primary CV outcome. The major reductions in many of the CV risk factors that were previously seen early in the trial had diminished differences over the nearly 10-year follow-up period, underscoring the difficulty in maintaining these interventions for a lifetime.[65]

There are certain interventions that can help reduce CV mortality in the setting of DM. Treating the “ABCs” (Hgb **A**1C%, **b**lood pressure, LDL-**C**) individually has been shown to reduce the rates of complications associated with DM, in particular CVD.[66–68] Importantly, research on comprehensive risk reduction shows additional effects when meeting goals with multiple risk factors.[66] A study from Wong et al. combined data from the **A**therosclerosis **R**isk **i**n **C**ommunities (ARIC) study, the **M**ulti-**E**thnic **S**tudy of **A**therosclerosis (MESA), and **J**ackson **H**eart **S**tudy (JHS) to examine CHD and CVD events in patients with DM.[69] Individuals with 1, 2, or all 3 risk factors at target levels had increasingly lower adjusted risks of CVD events of 36%, 52%, and 62%, respectively.

Another important aspect that the study was able evaluate was the risk reduction associated with control of these factors. Those at blood pressure goal had a 17% reduction for CVD events and CHD, whereas those at LDL-C goal had a 33% and 41% reduction, respectively. Similarly, those at Hgb A1c goal targets had a 37% and 36% reduction in CVD events and CHD.[69] The overall conclusion was that patients would ultimately benefit from achieving all 3 goals.

Several studies have compared revascularization for stable CAD vs intensive healthy behavioural intervention and optimal medical therapy including more aggressive blood pressure, lipid, and Hgb A1c goals as a means to reduce CV risk in patients DM. The **B**ypass **A**ngioplasty **R**evascularization **I**nvestigation **2 D**iabetes (BARI-2D) trial showed that revascularization in diabetic individuals with stable ischemic heart disease neither improved mortality nor decreased the rate of major CV events compared with optimal medical

therapy.[70] Hence, intensive behavioural modification is essential for improvement of CVD risk factors and reduction in mortality.[71] Comprehensive, multidisciplinary exercise-based cardiac rehabilitation (CR) programs are well validated care delivery models for optimal risk reduction.

CR for the MetS and DM

Comprehensive, multidisciplinary exercise-based CR for secondary prevention of CVD, inclusive of an individualized and tailored approach to patient care is an effective means of improving long-term outcomes.[72] The provision of CR involves medical evaluation, prescribed exercise, risk factor modification, health education, and counselling.[73] The services are delivered over 4 phases including phase I (inpatient), phase II (the transition to outpatient supervision of a tailored exercise prescription), and phases III and IV (maintenance phases stressing long-term behavioural pattern changes).[56] As discussed by Sandesara et al.[56] in ACCSAP 9 learning module published by the American College of Cardiology, the benefits of CR in patients with CVD include a reduction in total and CVD mortality by 14% and 26%, respectively. CR can reduce rates of hospitalization, angina, and depression within this population and improve overall quality of life.[56] Furthermore, improvement in the maximum oxygen consumption and brachial artery flow-mediated dilation has been noted with high-intensity interval training, with a lower mean resting heart rate and body weight seen with moderate-intensity continuous training.[74–76]

The MetS

The prevalence of MetS in the Canadian population was 21% among 18- to 79-year-old individuals, according to the 2013 results of the **C**anadian **H**ealth **M**easures **S**urvey (CHMS). The prevalence of MetS in the Canadian population appears to increase with age, with the condition in 13% of 18- to 39-year-old individuals and 39% of those aged 60-79 years.[77] The exercise capacity of those with MetS who participate in CR has been noted to be significantly lower than individuals without MetS, and outcomes of CR are poorer in those with MetS.[78]

Individuals with MetS benefit from efforts to increase enrollment in CR programs. A meta-analysis of 15 studies with 19,325 subjects reported that CR decreased the prevalence of MetS by 25%. There was also a protective role on all components of MetS, including waist circumference (−2.25 cm), LDL-C (−11.93 mg/dL), HDL-C (+2.13 mg/dL), fasting glucose (−6.42 mg/dL), and systolic (−6.2 mm Hg) and diastolic (−2.53 mm Hg) blood pressure.[73] These benefits correlate with participation in CR, noting a linear relationship between the cumulative number of CR sessions attended, and outcomes (6% lower risk of MI with every 6 CR sessions attended).[79]

CV risk factors are also improved by CR participation. Small but significant reductions in obesity indices such as weight and BMI have been shown, along with significant improvements in peak exercise capacity, HDL-C and CRP levels, and quality of life.[80]

DM

Healthy behaviour modification remain the most important approach to preventing DM, reducing risk almost twice as much as metformin alone.[81,82] In patients with DM, completion of CR is associated with a 54% reduction in mortality, 14% reduction in hospitalization, and 33% reduction in cardiac hospitalization.[83] There are data to support short-term, high-intensity (so-called “burst”) exercise over more traditional low-intensity, sustained exercise.[84] One study showed that in addition to greater improvement in their lipid profiles and BMI, patients who engaged in burst exercise experienced a 2.3-fold greater improvement in their Hgb A1c level ($P < 0.01$) than those who participated in sustained exercise.[84]

Despite benefits of CR, patients with DM are less likely to complete the full course of CR compared to nondiabetic individuals (41% vs 56%; $P < 0.0001$).[83] A meta-analysis published in the *Canadian Journal of Cardiology* revealed a sex difference of 4% (68.6% to 64.2% for men and women, respectively) in adherence to CR programs longer than 12 weeks’ duration because of significant barriers that limit optimal participation and completion of CR.[85]

Barriers to CR and Underutilization of Comprehensive CV Risk Reduction

Despite the well validated benefits of this approach to care, CR remains greatly underutilized. Of all eligible post-MI patients, less than 30% complete a prescribed program.[86,87] Factors affecting this include a lack of provider encouragement and patient participation once referred. Only 20% of patients eligible for CR are referred with major opportunities related to health system inadequacies.[56,88] Hospitals equipped with automated referral systems, such as the AHA's “Get with the Guidelines,” show far higher referral rates than the national average.[86] In addition, referrals in the general outpatient setting are on average 2 times lower than in cardiology or cardiac surgery clinics.[88] This is in part because of lack of familiarity with CR sites, limited access to proper referral forms, and logistical inconvenience for patients and providers.

The sociodemographic disparity apparent in the referral and utilization of CR is notable. Populations that have the lowest participation included women, uninsured patients, patients of low socioeconomic status, and elderly patients. A cross-sectional study also showed a low participation rate among rural patients.[89] There are many factors that promote this disparity. Cost is a prohibitive element for patients of low socioeconomic status or without adequate health insurance.[56,89] Similarly, distance travelled and transportation access to a CR site negatively affect participation rates in rural populations and for those of low socioeconomic status.[89] Despite the well-validated benefits of this approach to care, CR remains greatly underutilized. It is estimated that only about 30% of eligible post-MI patients complete a prescribed program. In one prospective study, 29% and 46% of patients participated in CR at 1 month and 6 months, respectively, from time of referral.[90] The proportion of patients referred to CR was observed to vary by 40% in a Canadian medical centre, according to the inpatient unit from which the patient was referred.[91] Importantly, the current model of CR delivery needs significant modification to overcome these barriers.

The Rebranding of CR

The current model of CR delivery has numerous barriers, and efforts to improve program access and utilization are needed. Innovative CR delivery models incorporating use of telemedicine, internet-based, home-based, and community-based programs need to be implemented to improve utilization of CR.[56,92] With increasing population access to the Internet and mobile phones, telemedicine programs are promising alternatives to conventional centre-based programs with the potential for improved accessibility and reduced costs.[56] A meta-analysis of 11 trials showed that CR delivered via telehealth was equally effective as centre-based CR for improving modifiable CV risk factors and adherence.[93] Furthermore, home-based programs delivered by qualified nonphysician health professionals have similar outcomes in terms of mortality and CV risk factor modification compared with traditional centre-based programs.[94]

Mobile health or “M-health,” which takes advantage of mobile and wireless capabilities is emerging as a great tool for providers to connect with and track individuals’ health status reliably and remotely. M-health is an emerging approach to care built upon the telemedicine movement which has yet to establish any conclusive evidence of outcomes improvement.[95–99]

These alternative delivery models should not replace conventional CR programs but instead should be used to help overcome barriers.[86]

Conclusions

The epidemic of MetS and DM continues to grow along with resultant consequences and complications. Comprehensive CV risk reduction is critical for this high-risk population. Health behaviour management with a focus on physical activity and diet is central to reducing ASCVD risk. Population health initiatives such as the AHA 2020, Canadian Diabetes Strategy, and World Heart Federation/WHO 25by25 are important for health promotion and disease prevention. Comprehensive, multidisciplinary exercise-based CR has well validated efficacy in reducing mortality in patients with CVD. CR is associated with a reduction in prevalence of MetS and provides a protective role in reducing negative risk factors associated with MetS. In diabetic individuals, CR participation is associated with reduced mortality and hospitalization in addition to improvements in lipid levels, BMI, fitness, and Hgb A1c levels. Despite these benefits, CR referral, enrollment, participation, and completion continue to be suboptimal because of barriers that confront patients and providers. Incorporating new care models and modes of CR delivery have the potential to enhance the benefits of comprehensive CV risk reduction and CR utilization.

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Table 1

AHA/NHLBI criteria for the clinical diagnosis of metabolic syndrome (any 3 of the following 5)

Measure	Categorical cut point
Elevated waist circumference *	≥ 102 cm (≥ 40 inches) in men;
	≥ 88 cm (≥ 35 inches) in women
Elevated triglycerides	≥ 150 mg/dL (1.7 mmol/L)
Reduced HDL-C	< 40 mg/dL (1.03 mmol/L) in men;
	< 50 mg/dL (1.3 mmol/L) in women;
	Or receiving drug treatment for reduced HDL-C
Elevated blood pressure	≥ 130 mm Hg systolic blood pressure;
	≥ 85 mm Hg diastolic blood pressure;
	Or receiving antihypertensive medication in a patient with a history of hypertension
Elevated fasting glucose	≥ 100 mg/dL;
	Or receiving drug treatment for elevated glucose level

AHA, American Heart Association; HDL-C, high-density lipoprotein cholesterol; NHLBI, National Heart, Lung, and Blood Institute.

Modified from Grundy et al.[2] with permission from Wolters Kluwer Health, Inc.

* ATP III clinical identification of the metabolic syndrome.

Table 2

IDF recommended waist circumference thresholds for abdominal obesity

	Men	Women
Europid	≥ 94 cm (37.0 inches)	≥ 80 cm (31.5 inches)
South Asian	≥ 90 cm (35.4 inches)	≥ 80 cm (31.5 inches)
Chinese	≥ 90 cm (35.4 inches)	≥ 80 cm (31.5 inches)
Japanese	≥ 85 (33.5 inches)	≥ 90 cm (35.4 inches)

IDF, International Diabetes Foundation.

Modified from Alberti et al.[3] with permission from Wolters Kluwer Health, Inc.