METABOLIC SYNDROME AND OBESITY: EPIDEMIOLOGY AND PREVENTION BY PHYSICAL ACTIVITY AND EXERCISE

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Obesity and physical inactivity comprise an important worldwide epidemic that has been linked to the metabolic syndrome. This syndrome is characterized by increased risk of hypertension, diabetes, inflammation, renal, and many other metabolic disorders. Presenting the prevalence of metabolic syndrome in selected world populations, this paper strongly discusses the pivotal role of physical activity and exercise in preventing central obesity, metabolic syndrome and their complications such as dyslipidemia, hypertension and insulin resistance. Exercise recommendations to decrease the risk of metabolic syndrome and its components as well as public health policies to promote public engagement on exercise are described. Regular practice of aerobic physical activities, such as walking, as well as weight-bearing exercise training are important to improve cardiovascular fitness, change body composition, and prevent or manage metabolic syndrome, obesity, diabetes, and other complications. [*J Exerc Sci Fit* • Vol 6 • No 2 • 87–96 • 2008]

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Introduction

Data from recent statistical surveys suggest that the prevalence of overweight and obesity is increasing worldwide. In Canada, the prevalence of overweight and obesity was 47.5% and 14.9%, respectively (Nishida & Mucavale 2005). Recent data from Brazil showed that overweight and obesity were 41.1% and 8.9%, respectively, in adult men, and 40.0% and 13.1%, respectively, in adult women (Instituto Brasileiro de Geografia e Estatística 2006). In Austrian farmers, the prevalence of overweight was 15.2%, and of obesity was 42.9% (Dorner et al. 2004).

In recent years, researchers have associated obesity with a newly diagnosed syndrome—the metabolic syndrome (MS). The overall prevalence of MS in Hong Kong was 2.5% of the population (Ko & Chan 2008), and it affected 6.1–11.6% (according to different diagnostic criteria) of Hong Kong adults (Chan et al. 2005). A cross-sectional population study in Beijing (China) reported that MS affected 13.2% of the population sample, and dyslipidemia was detected in 40.8% of females and in 51.9% of males (Li et al. 2006). In the United States, the prevalence of MS reached one quarter of the population (Park et al. 2003). In this context, the World Health Organization (WHO) has warned of the serious consequences of the "global epidemics of obesity and sedentarism". According to the WHO, about 60% of people around the world were sedentary, and physical inactivity causes approximately 2 million deaths from cancers, diabetes, ischemic heart disease, and stroke per year. Many efforts and strategies to confront the problem were described in the document "*WHO's Global Strategy on Diet, Physical Activity and Health*" (Waxman 2004).

Table 1 summarizes data on the prevalence of MS in selected populations around the world, which can vary according to different diagnostic criteria (Huang et al. 2008; Gentles et al. 2007; Lee et al. 2007; Lin et al. 2007; Pongchaiyakul et al. 2007; Agirbasli et al. 2006;

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Table 1. Prevalence of metabolic syndrome in selected populations

Country/region/city	Sample	Age (year)	Prevalence of MS	Reference
Australia	11,247 adults	25–75	15.8% (EGIR) to 18.2% (ATPIII)	Alberti et al. (2006)
China, Beijing	16,342 adults	20–90	10.2% (women), 15.7% (men)	Li et al. (2006)
Brazil, Cavunge	240 adults	25–87	38.4% (women), 18.6% (men)	de Oliveira et al. (2006)
Brazil, Ribeirao Preto	2063 young adults	23–25	4.8% (women), 10.7% (men)	Barbieri et al. (2006)
DECODE Study Group, 11 European cohort studies	5356 women, 6156 men	30–89	14.2% (women), 15.7% (men)	Hu et al. (2004)
France, Central-Western (DESIR cohort study)	4293 adults	30–64	7.0% (women), 10.0% (men)	Balkau et al. (2003)
France, Nancy in northeast	742 adults	28–64	5.4% (women), 7.2% (men)	Maumus et al. (2005)
China, Hong Kong	1513	18–66	9.6% (ATPIII) to 13.4% (WHO)	Ko et al. (2005)
China, Hong Kong	5202 diabetic patients	16–95	49.2–58.1%	Ko et al. (2006)
India, Jaipur	1800 adults	20	24.9%, 30.9% (women), 18.4% (men)	Gupta et al. (2004)
Iran	3036 children and adolescents	10–19	10.1%	Esmaillzadeh et al. (2006)
Italy, Bruneck	888 adults	40–79	17.8% (ATPIII) to 34.1% (WHO)	Bonora et al. (2003a, b)
Italy, Asti in northwest	1877 adults	45–64	22% (women), 24% (men)	Bo et al. (2005)
Italy, North	588 obese children	6–16	23.3%	Invitti et al. (2006)
Japan, Kagoshima	471 overweight or obese children	6–11	8.7% (overweight), 17.7% (obese)	Yoshinaga et al. (2005)
Japan	3264 adults	20–79	7.8%, 1.7% (women), 12.1% (men)	Arai et al. (2006)
Mexico	2158 adults	20–69	13.6% (WHO) to 26.6% (ATP III)	Aguilar-Salinas et al. (2004)
New Zealand	4022 adults	35–74	32% (Maori), 39% (Pacific/Polynesian aborigines), 16% (European descendants)	Gentles et al. (2007)
Vietnam, Ho Chi Minh	611 adults	18+	12%	Son et al. (2005)
Singapore cardiovascular cohort study	4334 adults	18–69	17.7% (IDF) to 26.2% (AHA)	Lee et al. (2007)
South Korea	6824 adults	20–80	15.0% (women), 13.5% (men)	Park et al. (2006)
Spain	429 obese children	4–18	18%	Lopez-Capape et al. (2006)
Spain, Valencia	7256 adults	45.4±9.8	10.2%	Alegría et al. (2005)
Turkey	1385 students	10–17	2.2%	Agirbasli et al. (2006)
Turkey, Izmir	450 adult men	24–60	17.8%	Demiral et al. (2006)
Taiwan	124,513 adults	20–94	13.9% (IDF criteria) to 22.4% (AHA criteria)	Huang et al. (2008)
Taiwan, Taichung	2359 adults	40–64	24.19% (women), 35.32% (men)	Lin et al. (2007)
		65+	51.82% (women), 43.23% (men)	
Thailand	602 adults	20–90	15%	Pongchaiyakul et al. (2007)
USA, 3rd NHANES survey	12,363 adults	20	23%	Park et al. (2003)
USA, Pittsburgh & Memphis	3075 older adults	70–79	39%	Goodpaster et al. (2005)

EGIR = European Group for the Study of Insulin Resistance; ATPIII = Adult Treatment Panel III; WHO = World Health Organization; IDF = International Diabetes Federation; AHA = American Heart Association.

Alberti et al. 2006; Arai et al. 2006; Barbieri et al. 2006; de Oliveira et al. 2006; Demiral et al. 2006; Esmaillzadeh et al. 2006; Invitti et al. 2006; Lopez-Capape et al. 2006; Park et al. 2006; Ko et al. 2006; Li et al. 2006; Alegría et al. 2005; Bo et al. 2005; Goodpaster et al. 2005; Maumus et al. 2005; Son et al. 2005; Yoshinaga et al. 2005; Aguilar-Salinas et al. 2004; Gupta et al. 2004; Hu et al. 2004; Balkau et al. 2003; Bonora et al. 2003a). It should be emphasized that in diabetic patients, the risk of MS rose from 4- to 6-fold compared to nondiabetic subjects (Ko et al. 2005, 2006).

The Burden of MS: From Obesity to Diabetes

Excessive caloric intake and low levels of physical activity promotes the development of subcutaneous, perivisceral and intravisceral fat deposits. Although genetic predisposition was a very important factor, sedentary lifestyle such as excessive TV watching has been implicated as an important risk factor for both obesity and diabetes in women (Hu et al. 2003). Children were usually exposed to obesity risks, such as higher and frequent intake of junk foods like high-fat snacks and soft drinks, as well as poor ingestion of fruits and vegetables (Jimenéz-Cruz et al. 2002). Nevertheless, unhealthy dietary behaviors in children will eventually influence obesity later in life (Wang et al. 2003). It has been estimated that each 1 kg increase in body weight is associated with a 9% increment in the risk of type II diabetes (Levetan 2001). The Physician's Health Study reported that obesity (BMI ≥ 30) was strongly associated with the risk of both ischemic and hemorrhagic stroke, and each unit increment in BMI was related to a 6% increase in the risk of stroke (Kurth et al. 2002). Obesity has been associated with decreased life expectancy, especially when BMI is higher than 45 (i.e. morbid obesity) (Fontaine et al. 2003), and it increased cancer mortality in women and men by 62% and 52%, respectively (Calle et al. 2003). There was a scientific consensus suggesting that obesity, insulin resistance, type II diabetes mellitus, and hypertension were associated with sedentarism, excessive caloric intake, and consecutive weight gain in MS. This syndrome increased the risk of carotid as well as coronary atherosclerotic disease and was an independent predictor of coronary vascular disease risk (Saely et al. 2005; Bonora et al. 2003b). Table 2 summarizes the WHO (1999) and Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (2001) criteria for the clinical diagnosis of MS. Recently, the International Diabetes Federation proposed a new worldwide consensus regarding MS (Table 3) (Alberti et al. 2006; IDF 2006).

Physical Activity, Exercise, and Physically Active People

According to Caspersen et al. (1985), physical activity is "any bodily movement produced by skeletal muscles that results in energy expenditure"; exercise is a subset of physical activity that is planned, structured,

Table 2. Diagnostic criteria for metabolic syndrome (MS) according to the World Health Organization (WHO) and Adult Treatment Panel III (ATPIII)

WHO criteria (1999)		ATPIII criteria (2001)	
Presence of diabetes or insulin resistance plus at least two of the following criteria		People with three or more of the following criteria are considered positive for MS	
Waist-to-hip ratio	> 0.90 in men; > 0.85 in women	Abdominal obesity (waist circumference)	> 102 cm in men; > 88 cm in women
Serum triglycerides OR HDL cholesterol	≥ 1.7 mmol/L < 0.9 mmol/L in men; < 1.0 mmol/L in women	Plasma triglycerides	> 150 mg/dL
Blood pressure	≥ 140/90 mmHg	Blood pressure	> 130 ± 85 mmHg
Urinary albumin excretion rate OR Albumin-to-creatinine ratio	> 20 μg/min ≥ 30 mg/g	HDL cholesterol	< 40 mg/dL in men; < 50 mg/dL in women
		Glucemia	> 110 mg/dL

Table 3. New International Diabetes Federation definition of metabolic syndrome

A person is defined as having metabolic syndrome when central obesity and two of the following four factors are present:	
Raised triglycerides	≥ 150 mg/dL (1.7 mmol/L)
Reduced high-density lipoprotein cholesterol	≤ 40 mg/dL (1.03 mmol/L) in males; ≤ 50 mg/dL (1.29 mmol/L) in females
Raised blood pressure	Systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg
Raised fasting plasma glucose	≥ 100 mg/dL (5.6 mmol/L)

From: International Diabetes Federation (2006), page 10.

and repetitive. The same authors stated that physical fitness is a collection of health or skill-associated attributes. Body composition, cardiorespiratory endurance, muscular strength and endurance, and flexibility are components of health fitness, whereas balance and coordination, agility, power, reaction time, and speed comprise skill-related fitness (European Food Information Council [EUFIC] 2006). Sport can be defined as being a set of physical activities that involves structured competitive situations with norms and rules; many countries have adopted the term sport to refer to all exercise and leisure-time physical activity (EUFIC 2006). According to the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine, physically inactive or sedentary subjects were defined as those who did not engage in at least 150 minutes of physical activities per week (Pate et al. 1995).

Cardiorespiratory Fitness is Inversely Associated with Obesity, MS and Chronic Disease

It has been recognized that lower cardiopulmonary fitness was strongly associated with cardiovascular mortality and all-cause mortality; higher mortality risk was observed in men with obesity and low fitness level, as well as in obese men with diabetes mellitus (Wei et al. 1999). In this respect, even participation in non-vigorous regular physical activities five or more times per week was positively associated with insulin sensitivity (Mayer-Davis et al. 1998). In a South African population study, subjects who had the highest degree of physical activity had 62% lower risk of obesity (Kruger et al. 2002). In the same way, long-term physical activity, independently of BMI, is inversely associated with breast cancer risk in middle-aged women (Breslow et al. 2001).

Lower cardiorespiratory fitness was associated with increased risk of MS, whereas men in the higher tertile of maximum oxygen consumption (VO_{2max}) had 75% less risk of developing MS than sedentary men (Laaksonen et al. 2002). Men who practiced ≥ 3 hours/week of moderate to vigorous physical activities had 50% less risk of developing MS in comparison to the sedentary group.

Type II diabetes mellitus, a component of MS, could be prevented by lifestyle modifications. In a Finnish prospective study, people were educated to decrease both energy intake, total fat and saturated fat, and also motivated to increase fiber intake and physical activity. After a follow-up of 3.2 years, the intervention group had a 58% decreased risk of diabetes (Tuomilehto et al. 2001), confirming previous data from the *Da Qing IGT and Diabetes Study* that reported a significant 46% reduction in the risk of diabetes in the exercise-intervention group compared to control subjects (Pan et al. 1997). Physical activity or exercise, even without weight loss, can improve both body composition and insulin sensitivity according to observational and experimental human studies (Ross 2003; Snitker et al. 2003). Results from the cohort of the *Aerobics Center Longitudinal Study* reported that lower cardiorespiratory fitness, overweight and obesity increased cardiovascular mortality in diabetic men by 170%, 170% and 180%, respectively (Church et al. 2005), confirming previous findings that high fitness level was inversely associated with fibrinogen, white blood cell count, uric acid and MS risk, whereas fatness level was positively linked to all variables (Church et al. 2002).

Cardiovascular Protection of Exercise

Hypertensive men who practiced vigorous physical activities had reduced adjusted relative risks for total mortality (0.43) and cardiovascular mortality (0.33) in a cohort study from Malmo, Sweden (Engstrom et al. 1999). Representative data from 9824 US subjects revealed that participation in moderate or vigorous physical activities was linked to a 38% decrease in the total mortality risk, and that active individuals at high risk of cardiovascular disease had a 45% lower mortality risk (Richardson et al. 2004).

Consistent weight loss induced by a very low calorie diet improved vasodilatory-mediated blood flow, associated with decreased plasma glucose levels (Raitakani et al. 2004). Similar effects could be obtained by physical exercise and diet. Aerobic training improved endothelium-dependent and independent vasodilatory mechanisms in patients suffering from chronic heart failure (Maiorana et al. 2000) and also older subjects submitted to resistance training (Rywik et al. 1999).

Researchers noted that endurance-trained middle-aged and older men had 20–35% improvement in central artery compliance than sedentary men (Tanaka et al. 2000). The same authors reported that 3-month aerobic exercise training also enhanced arterial compliance of middle-aged and older people.

In a clinical controlled trial that tested the benefits of both calorie intake reduction and increase in weekly physical activities, a reversal in erectile dysfunction in about one third of the obese men was observed (Esposito et al. 2004).

Although extremely short, a 3-week intervention with a low-fat, high-fiber diet plus 45–60 minutes of daily walking at an intensity of 70–85% of maximal heart rate improved blood lipid profile, decreased both systolic and diastolic blood pressure, and lowered fasting blood glucose and a prostaglandin marker (8-iso-$PGF_{2\alpha}$), but enhanced urinary nitric oxide values (Roberts et al. 2002).

Dyslipidemic MS patients have lower blood levels of high-density lipoprotein (HDL) than healthy controls. These low levels of HDL had more impact on early carotid atherosclerosis in male MS patients, whereas high blood glucose levels were better associated with carotid atherosclerosis in the female MS group (Iglseder et al. 2005). It seemed that exercise could benefit those patients by improving hepatic HDL synthesis and release. The *Los Angeles Atherosclerosis Study* (USA) confirmed that people who engaged in vigorous physical activities (> 3.5 times/week) had minor carotid wall thickness, lower body mass index and resting heart rate, and higher level of HDL in blood compared to the sedentary individuals (Nordstrom et al. 2003). This confirmed results from a previous study reporting that regular practice of aerobic exercise reduced postprandial values of plasma triglycerides, very low-density lipoprotein, and chylomicron-cholesterol particles in diabetic patients when compared to the diabetic sedentary group (Sánchez-Juan et al. 2001). In the same context, Jen et al. (2005) found that a high-cholesterol diet induced impairment of endothelium-dependent and -independent vasodilation of femoral arteries in rabbits; however, 2 months of treadmill running reversed this deleterious effect. However, another study has observed an opposite effect of exercise. Exercise practice in elderly human subjects with hypercholesterolemia was associated with increased arterial blood pressure (Vacanti et al. 2005).

Regular practice of physical exercise was an evidence-based strategy to control blood pressure (Stewart et al. 2005). Endothelin-1 is an important vasoconstrictor that controls vascular tone and its overexpression is linked to hypertension. Data from the *Heritage Family Study* and other important research have pointed out that regular practice of aerobic exercise, at least three times per week, could counteract the influence of an endothelin-1 genotype on hypertension (Rankinen et al. 2007; Van Guilder et al. 2007). Other important lifestyles practices of dietary approaches to stop hypertension (DASH) included decreased salt (NaCl) intake, weight loss, moderate alcoholic ingestion, and increment of dietary potassium (Appel 2003).

Effects of Exercise Against MS, Obesity, and Diabetes

The major importance of exercise for obesity prevention and treatment is its capacity to change body composition. A 16-week strength training program in older men was sufficient to enhance fat-free mass by 2 kg and decrease total fat mass by the same amount. The increment in fat-free mass in the arms, legs, and trunk was 0.380 g, 0.715 g, and 0.640 g, respectively (Treuth et al. 1994). A strength-training study in young adults, using 8–12 repetition maximum (RM) over the course of 16 weeks, reported decreased fat mass, and increased fat-free and skeletal mass by 2.6 kg and 4.2 kg, respectively (Abe et al. 2003). Compared with the lowest category, men in the highest strength group had 44% lower risk of developing MS (Jurca et al. 2005). Strength training was also very important in improving insulin sensitivity in men and women (Cheng et al. 2007).

As previously described, obesity, especially its abdominal pattern, increased the risk of hypertension and all pathologies of the MS. Greenfield et al. (2003) studied 684 female twins and reported that the group with regular engagement in recreational physical activities had the same lowest blood pressure values found in the low genetic risk group. A net weight reduction of 5.1 kg as a result of increased physical activity, dietary calorie restriction or both could decrease both systolic and diastolic blood pressure by 4.44 mmHg and

3.57 mmHg, respectively (Neter et al. 2003). A simple 5% weight reduction in obese women lowered systolic blood pressure by 7 mmHg and was associated with decreased levels of angiotensinogen (–27%), renin (–43%), angiotensin-converting enzyme (–12%), aldosterone (–31%), and angiotensinogen expression in adipocytes (–20%) (Engeli et al. 2005).

MS and obesity increased the risk of renal hypertension and microalbuminuria, through the following pathogenic mechanisms (Chen et al. 2004; Hall 2003): (1) increase in renal sympathetic activity; (2) activation of the renin-angiotensin-aldosterone system; (3) hyperinsulinemia; and (4) obesity-induced glomerulopathy.

It also appeared that exercise training could reverse the deleterious vasodilatory impairment induced by high glucose levels in the kidneys (De Moraes et al. 2005).

Sedentarism has been suggested to be involved with a mild systemic proinflammatory state characterized by higher levels of C-reactive protein (CRP), interleukin (IL)-6 and fibrinogen (Kullo et al. 2007). It has been suggested that physical activity and exercise decreases inflammation—an important feature in MS. Studies suggested that an active lifestyle was linked to decreased levels of MS markers such as white blood cell count, CRP, fibrinogen, IL-6, and soluble tumor necrosis factor-α receptors (Pischon et al. 2003; Ford 2002; Geffken et al. 2001).

In another study of dietary calorie restriction (900–1200 kcal balanced diets) or calorie restriction plus exercise intervention, significant improvements in overweight children were observed. The exercise intervention consisted of circuit training with 9 workout stations twice per week in the first 6 weeks and then once per week up to 1 year. During the 75 minutes of a training session, at an intensity of 60–70% of the predicted maximum heart rate, children performed 30 minutes of resistance training, 10 minutes of aerobic dancing, 10 minutes of agility training, 10 minutes of warm up, 5 minutes of cool down, and rest periods between stations. The intervention significantly improved carotid wall thickness, endothelial function, LDL/HDL cholesterol ratio, waist-to-hip ratio, and percent body fat (Woo et al. 2004). In the same context, exercised mice had reduced vessel neointima formation, decreased numbers of endothelial foam cells (macrophages with cytoplasm accumulation of oxidized LDL), and lower levels of fibrinogen and plasminogen activator inhibitor-1 (PAI-1) (Pynn et al. 2004). Another study showed that weight reduction by diet and aerobic exercise significantly reduced blood pressure and improved dyslipidemia in hypertensive MS patients (Christ et al. 2004).

Although weight loss by diet has been more effective in decreasing inflammation, exercise training could also decrease proinflammatory cytokine release from the immune system, as well as stimulate the synthesis of anti-inflammatory mediators in adipocytes. Exercise also influenced adipocytes by hindering their production of proinflammatory mediators and inhibited liver synthesis of CRP, fibrinogen, and other hepatic inflammatory signals (Nicklas et al. 2005). After 6 months of aerobic exercise training, 23% decline in PAI-1 levels in patients with peripheral artery disease was observed (Killewich et al. 2004). Exercise also helped to decrease other inflammatory markers like monocyte-chemoattractant protein-1 and IL-8 in MS subjects (Troseid et al. 2004).

Public Health Recommendations to Confront MS and Obesity

The CDC and the American College of Sports Medicine suggested that 30 minutes of moderate intensity physical activity should be done on most if not all days of the week in order to promote health (Pate et al. 1995). This 30 minutes of physical activity could be achieved in three 10-minute sessions and is equivalent to an energy spend of 1500 kcal a week. Specifically, for diabetic patients, it was recommended that they engage in the same weekly amount of physical activity, i.e. 150 minutes of moderate intensity aerobic physical activity (40–60% of VO_{2max} or 50–70% of maximum heart rate), or 90 minutes of aerobic exercise (> 60% of VO_{2max} or > 70% of maximum heart rate) (Sigal et al. 2004). Six months of resistance training improved insulin resistance in elderly people (Ryan et al. 2001). In this context, walking seemed to be optimal to decrease MS risk. Women who walked at least 2.5 hours per week had a 30% reduction in cardiovascular risk; walking at 3.2–4.8 km/hr or at 4.8–6.4 km/hr reduced the risk of cardiac events in 14% and 24%, respectively (Manson et al. 2002). Diabetic patients who walked at least 2 hours a week had decreased total mortality (–39%) and cardiovascular mortality (–34%). From the same study, among those who walked 3–4 hours/week, the reductions in total mortality and cardiovascular mortality were even more pronounced (–54% and –53%, respectively) (Gregg et al. 2003).

Following this approach, Table 4 summarizes the current recommendations with regard to exercise and physical activities to prevent and manage MS and obesity (United States Department of Health and Human Services 2005; Tudor-Locke & Bassett 2004).

Table 4. Exercise recommendations to prevent and manage metabolic syndrome and obesity

To increase cardiovascular fitness: engage in at least 30 minutes of moderate-intensity physical activity, above usual activity, at work, home or school on most days of the week
To improve muscle mass: engage in 2–3 sessions of strength/resistance exercises such as working out with elastic bands, weights, stability balls, and body bars
To avoid body weight gain: engage in approximately 60 minutes of moderate- to vigorous-intensity physical activities (or exercises) on most days of the week, and do not exceed calorie intake requirements
To sustain body weight loss: engage in 60–90 minutes of daily moderate-intensity physical activity; consult your physician before starting an exercise program
Walk at least 10,000 steps on most days of the week

Based on: United States Department of Health and Human Services and United States Department of Agriculture (2005); Tudor-Locke and Bassett (2004); Pate et al. (1995).

Table 5. Public policy strategies to improve physical activity practice and research in developing countries

• Creation of a *Sports, Leisure and Recreation Ministry* and/or improvement of its funding resources • Improvement of funding programs to support sports, leisure, and recreation structure, including private sector participation • Construction of adequate installations for physical education, leisure, and sport practice in every public school • Creation of national and regional programs with active participation of universities and research laboratories to monitor body mass index, body composition, bone mass density, metabolic state, and practice of healthy dietary habits in the population • Creation of a national program to promote the regular practice of physical activity at least during the weekends with local public (prefectural) and private efforts	• Promotion of physical activity and sport in occupational environments • Construction of Olympic villages in all states or territories of a country • Construction of at least one sports center in every small town • Improvements in facilities for physical activity, such as athletics gyms, recreation and sports gyms, swimming pools, football pitches, cycling tracks, etc. • Creation and/or development of municipal councils to plan and carry out local community initiatives on physical activity, sports, and recreation participation

In weight loss interventions through exercise and/or diet, an energy expenditure of 3500 kcal is necessary to cause a 400–450 g of body fat loss. This energy expenditure is equivalent to 60–90 minutes of intense physical activity, such as brisk walking. One of the most important MS component is central obesity measured by waist circumference (Ferrari 2007a). Regular exercise practice, independently of weight loss, decreased total body fat, visceral fat and increased leanness, which have been linked to improved insulin and blood lipids as well as diastolic blood pressure (Stewart et al. 2005). Recent data have shown that a 3 cm reduction in waist circumference improved MS (Miyatake et al. 2008).

The WHO has sponsored national and regional *Public Health Programs* to promote physical activity. A successful example is the *Agita São Paulo Program*, coordinated by CELAFISCS. During the 1999–2002 period, this workgroup observed that physical fitness increased from 9.5% to 24% in Sao Paulo, the most populated Brazilian State (Matsudo et al. 2003). Promotion of physical fitness as a school-based strategy has been associated with better glycemic control and improvement of both cardiovascular performance and body composition (Carrel et al. 2005). These initiatives were important in decreasing the amount of TV watching and increasing daily energy expenditure by promoting physical activities that were crucial in preventing obesity in children using school-based programs (Robinson 2003). Exercise promotion to decrease chronic disease risk is also important in adults and the middle-aged since it can slow down the functional decline associated with aging (Ferrari 2007b).

Considering that many developing countries have few places for recreation and sports practice, Table 5 summarizes the current recommendations for improving physical activity practice and research around the world.

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