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Physical Activity, Physical Fitness and Metabolic Syndrome

Xiaolin Yang

*LIKES-Research Center for Sport and Health Sciences, Jyväskylä,
Finland*

1. Introduction

The metabolic syndrome is recognized as one of the leading worldwide health problems, which is a constellation of metabolic risk factors that is associated with increased risk for developing cardiovascular disease, type 2 diabetes mellitus and myocardial infarction. Clustered metabolic risk factors include abdominal obesity, dyslipidemia, elevated blood pressure, glucose intolerance, and insulin resistance, as standardized by the international criteria [1]. Evidence from observational epidemiological studies indicates that the metabolic risk factors begin early in life [2,3]. Childhood overweight and obesity are closely associated with insulin resistance, in which result the development of metabolic syndrome. The overall prevalence of metabolic syndrome can be identified in children and adolescents. Obesity and insulin resistance may develop the metabolic syndrome during the early years of life and throughout in adulthood. In Finland, the prevalence of metabolic syndrome has increased dramatically over the past decades [4,5].

The benefits of physical activity and physical fitness on the health of the general population have been attested beyond dispute [6]. There is overwhelming evidence that participation in regular, moderate-intensity physical activity may be a preventive intervention of the metabolic syndrome and that activity of greater intensity may provide even greater benefit [7]. Remarkably, supervised exercise training in either aerobic exercise or resistance training may be an effective adjunctive treatment and produce significant functional benefits for individuals with the metabolic syndrome [8]. Physical activity and exercise are thus uniquely positioned to improve physical and psychosocial health and function by reducing the clustered metabolic risk and, in turn, by delaying or avoiding the onset of diabetes and cardiovascular diseases. However, most of the studies have been cross-sectional, but a few have been longitudinal.

The aim of this chapter is to outline physical activity and fitness to prevent or reduce the prevalence or incidence of metabolic syndrome among youth and adults. I start with the definition of physical activity, cardiorespiratory fitness and muscular strength and proceed to a discussion of the role of physical activity and fitness on the metabolic syndrome. I will discuss the importance of physical activity and fitness as their primary sources of health information that affect the metabolic syndrome in both youth and adults. Special emphasis is given to the use of long-term physical activity as a possible means of effectively reducing the prevalence of metabolic syndrome.

2. Rationale of physical activity and fitness in the prevention of metabolic syndrome

2.1 Definitions

The terms 'physical activity', 'exercise' and 'physical fitness' have been described in detail by Caspersen et al. [9]. Although these terms are related and have similar meanings, they aren't identical in meaning. Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure. Exercise is a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness. Physical fitness is a set of attributes that are either health-related (i.e. cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility) or skill-related (i.e. agility, balance, coordination, speed, power, and reaction time). Physical fitness is also referred to almost exclusively as cardiorespiratory fitness (also called cardiovascular fitness or maximal aerobic power), which relates very closely to maximal capacity for oxygen consumption. An important distinction between physical activity and fitness is the intraindividual day-to-day variability; physical activity will undoubtedly vary on a daily basis, whereas cardiorespiratory fitness will remain relatively static, taking time to change. This variability will impact on the ability to measure these two quantities and consequently will influence the ability to demonstrate their relationship with metabolic outcomes. In this chapter physical activity will be used as a generic term, whereas cardiorespiratory fitness and muscular strength will be used in their specific meanings. Based on previous studies of assessments of physical activity and physical fitness, the main methods of these standard measures have been summarized and presented in Table 1.

The term 'metabolic syndrome' is generally defined as the clustering risk factors associated with medical disorders that increase the risk of developing atherosclerotic and insulin resistance, i.e. elevated levels of central adiposity, hypertension, dyslipidemia, impaired glucose metabolism, and a low level of high-density lipoprotein cholesterol [10]. Table 2 summarizes five international criteria in the following: World Health Organization [11], European Group for the Study of Insulin Resistance [12], American College of Endocrinology/American Association of Clinical Endocrinologists [13], International Diabetes Federation [14], and National Cholesterol Education Program Adult Treatment Panel III [10].

The World Health Organization criteria requires the presence of impaired glucose tolerance, impaired fasting glucose, type 2 diabetes, and insulin resistance in top quartile of non-diabetic population and at least two of the following: waist:hip ratio > 0.9 in men and > 0.85 in women, serum triglycerides ≥ 1.7 mmol/L, systolic/diastolic blood pressure $\geq 140/90$ mmHg or medication, high-density lipoprotein cholesterol ≤ 0.9 mmol/L in men and ≤ 1.0 mmol/L in women, and microalbuminuria: urinary albumin excretion ratio ≥ 20 $\mu\text{g}/\text{min}$ or albumin:creatinine ratio ≥ 30 mg/g. The European Group for the Study of Insulin Resistance criteria includes the presence of hyperinsulinemia (defined as nondiabetic subjects having fasting insulin level in the highest quartile) and at least two of the following abnormalities: fasting plasma glucose ≥ 6.1 mmol/L (110 mg/dL), triglycerides > 2.0 mmol/L, high-density lipoprotein cholesterol < 1.0 mmol/L or medication, systolic/diastolic blood pressure $\geq 140/90$ mmHg or current use of antihypertensive medication, and waist circumference ≥ 94 cm in men and ≥ 80 cm in women. The American College of Endocrinology/American

<i>Physical activity</i>	Children and adolescents	Adults
Questionnaire	Physical activity at school Organized sport Non-organized sport Commuting to school Leisure activities Time spent sitting	Sports Occupation Household/Caregiving Transportation Conditioning Leisure/Recreation activities Time spent sitting
Interview	Face to face	Face to face Telephone
Instrument	Heart rate monitoring Pedometer Accelerometer	Heart rate monitoring Pedometer Accelerometer
Physical fitness	Laboratory	Epidemiologic
Cardiorespiratory	Maximum oxygen uptake on treadmill or cycle ergometer	12-minutes run 1-mile walk Bench (30 cm high) step
Body composition	Underwater weighing Near infrared Bioelectrical impedance analysis	Waist girth / waist-to-hip ratio Body mass index (kg/m ²) Skinfolds (biceps, triceps, abdomen, suprailium, subscapula and thigh)
Muscular strength and endurance	Dynamometer Cable tensiometer Load cells Strain gauges	Handgrip Chin ups Push ups Sit / Curl ups
Flexibility	Leighton flexometer	Sit-and-reach flexometer

Table 1. Main assessment of physical activity and physical fitness

Association of Clinical Endocrinologists criteria requires the presence of abdominal obesity (waist circumference ≥ 102 cm in men and ≥ 88 cm in women) and at least two of the following abnormalities: fasting plasma glucose ≥ 5.6 mmol/L (100mg/dL), systolic/diastolic blood pressure $\geq 130/85$ mmHg or medication, triglycerides ≥ 1.7 mmol/L (150 mg/dL) or medication. The International Diabetes Federation criteria includes the presence of abdominal obesity (waist circumference ≥ 94 cm in men and ≥ 80 cm in women) and ≥ 2 of the following four indicators: fasting plasma glucose ≥ 5.6 mmol/L (100 mg/dL), triglycerides ≥ 1.7 mmol/L (150 mg/dL), high-density lipoprotein cholesterol < 40 mg/dL (1.03 mmol/L) in men and < 50 mg/dL (1.29 mmol/L) in women, and systolic/diastolic blood pressure $\geq 130/85$ mmHg or treatment for hypertension. The National Cholesterol Education Program Adult Treatment Panel III criteria includes the presence of at least three of the following: waist circumference ≥ 102 cm in men and ≥ 88 cm in women, triglycerides ≥ 150 mg/dL, high-density lipoprotein cholesterol < 40 mg/dL in men and < 50 mg/dL in women, systolic/diastolic blood pressure $\geq 130/85$ mm Hg or use of medication for hypertension, and fasting plasma glucose ≥ 5.6 mmol/L (100 mg/dL) or medication.

	WHO (1999)	EGIR (1999)	ACE/AACE (2003)	IDF (2006)	NCEP-ATP III (2005)
Required criteria	IGT, IFG, T2D, insulin resistance in top quartile of non-diabetic population	Insulin resistance in top quartile of non-diabetic population	High risk ¹⁾ , WC > 102 cm (M) or > 88 cm (F)	WC ≥ 94 cm (M) or ≥ 80 cm (F), and WC with ethnicity specific values, or BMI > 30 kg/m ²	
Other criteria	plus ≥ 2 of the following:				
Waist circumference (WC)	WHR > 0.9(M), or >0.85 (F); or BMI > 30 kg/m ²	≥ 94 cm (M) or ≥ 80 cm (F)			≥102 cm (M) or ≥ 88 cm (F)
Triglyceride	≥ 1.7 mmol/L	≥ 2.0 mmol/L	≥ 1.7 mmol/L (150 mg/dL)	≥ 1.7 mmol/l (150 mg/dL) or medication	≥ 150 mg/dL
High-density lipoprotein cholesterol	≤ 0.9 mmol/L (M) or ≤ 1.0 mmol/L (F) or medication	< 1.0 mmol/L or medication	< 40 mg/dL (M) or < 50 mg/dL (F)	< 40 mg/dL (1.03 mmol/L) (M) or < 50 mg/dL (1.29 mmol/L) (F)	<40 mg/dL (M) or <50 mg/dL (F)
Blood pressure	≥ 140/90 mmHg or medication	≥ 140/90 mmHg or medication	≥ 130/85 mmHg or medication	≥ 130/85 mmHg or medication	≥130/85 mmHg or medication
Glucose		≥ 6.1 mmol/L (110 mg/dL)	≥ 5.6 mmol/L (100 mg/dL)	≥ 5.6 mmol/L (100 mg/dL)	≥5.6 mmol/L (100 mg/dL) or medication
Other	Microalbuminuria; UAER ≥ 20 µg/min or ACR ≥ 30 mg/g				

WHO, World Health Organization, EGIR, European Group for the Study of Insulin Resistance; ACE/AACE, American College of Endocrinology/ American Association of Clinical Endocrinologists; IDF, International Diabetes Federation; NCEP-ATP III, National Cholesterol Education Program- Adult Treatment Panel III; IGT, impaired glucose tolerance; IFG, impaired fasting glucose, T2D, type 2 diabetes; WHR, waist:hip ratio; BMI, body mass index; UAER, urinary albumin excretion ratio; ACR, albumin:creatinine ratio.

¹⁾High risk: family history of type 2 or gestational diabetes, known cardiovascular disease, polycystic ovary syndrome, physically inactive lifestyle, >40 years of age, and ethnic populations at high risk for type 2 diabetes. M = male, F = female.

Table 2. Metabolic syndrome definitions and diagnosis issued by international criteria

It has been noted that these definitions overlap but differ in the points of emphasis of the components. Using the above definitions of the metabolic syndrome, there are quantitatively significant differences in sample sizes, age groups and rates of healthy participants as well. For example, the International Diabetes Federation definition identifies a high degree of overlap among the participants with the metabolic syndrome using the

National Cholesterol Education Program Adult Treatment Panel III criteria. The two definitions similarly classified approximately 93% in 3601 American adults aged ≥ 20 years [15], 85% in 2182 Finnish young adults aged 24–39 years [4], and only about 16% in 5047 Swedish adults aged 46–68 years [16].

2.2 Systemic mechanisms

In general, leisure-time physical activity and aerobic exercise may provide an advantage in helping reducing the metabolic syndrome in middle-aged and elderly population. The potential mechanisms are often proposed by which physical activity and fitness can reduce the risk of the metabolic syndrome in response to insulin resistance and abdominal obesity. From a psychosocial standpoint, physical activity and fitness have a beneficial effect that can improve psychosocial well-being, leading to better mood, higher self-efficacy and stronger social motives for exercise [17,18]. Participation in regular physical activity or aerobic exercise is an effective way to establish lifelong habits for reducing the increased risk of insulin resistance and obesity. Individuals who want to maintain physical abilities may have better awareness of other health-related habits such as diet, smoking and sedentary lifestyle, all of which have been found to be related to the risk for the metabolic syndrome [19,20]. Increased physical activity and fitness may also lead to enhanced overall cardiovascular function and muscular endurance which, in turn, delay the onset or help prevent the development of metabolic syndrome. These psychosocial effects may then interact with biological processes that may result in reduction of subclinical inflammation involving cytokines derived from adipose tissue and modulation of various adipocytokines that lead to reduce the prevalence of metabolic syndrome [21]. The benefit of increased and maintained physical activity and physical fitness may be directly or indirectly associated with reduced incidence of the metabolic syndrome.

However, the relationship between physical activity or physical fitness and the metabolic syndrome may also be bidirectional. The prevalence of metabolic syndrome may lead to declining levels of physical activity and fitness as symptoms of metabolic syndrome may increase sedentary lifestyle, unhealthy diet, low energy level and lack of exercise and physical activity. Therefore, the precise mechanisms underlying the effect of physical activity and fitness on the metabolic syndrome still need further clarification.

3. Effect of physical activity and fitness on metabolic syndrome in adults

A number of cross-sectional epidemiological studies have been conducted to examine the effect of leisure-time physical activity and cardiorespiratory fitness on the metabolic syndrome in adult population over the last decade. Several studies have only focused on the association in men. An English cohort of 711 employed middle-aged men demonstrated a dose-relationship between both leisure-time physical activity and cardiorespiratory fitness and the clustering of the metabolic syndrome including fasting glucose, triglycerides, high-density lipoprotein cholesterol, blood pressure, and body mass index [22]. Men with higher physical activity, as defined by a physical activity index, were found to be less likely to have the metabolic syndrome when compared with the inactive ones. The age-adjusted odds ratios and their 95% confidence intervals for having the clustering of metabolic syndrome were 0.56 (0.33-0.96) for occasional/light physical activity, 0.37 (0.19-0.71) for moderate/moderately vigorous physical activity, and 0.12 (0.03-0.50) for vigorous physical activity. Men with moderate to high levels of the fitness were also found to be less likely to

develop the metabolic syndrome when compared with those with unfit. The corresponding age-adjusted odds ratios and 95% confidence intervals were 0.27 (0.15-0.46) in the moderate fitness category and 0.18 (0.09-0.33) in the high fitness category compared to the unfit group. A similar study design and analysis was performed in a Finnish study of 1 069 middle-aged men [23]. Leisure-time physical activity, as measured by metabolic equivalent hours per week (MET h·wk⁻¹), was divided into three levels of intensity: low, moderate and high. The each level was grouped again into three categories from low to high. Men who engaged in moderate-intensity physical activity (<1.0 h·wk⁻¹) were 60% more likely to have the metabolic syndrome than those engaging in physical activity (≥ 3.0 h·wk⁻¹). Men with low fitness (VO_{2max} ≤ 29.1 ml·kg⁻¹·min⁻¹) were approximately seven times more likely to have the metabolic syndrome than those with high fitness (VO_{2max} ≥35.5 ml·kg⁻¹·min⁻¹). The relationships remained significant after adjustment for confounders.

In the Whitehall II study, which assessed a dose-response relationship between leisure-time physical activity and metabolic syndrome in 5 153 Caucasian civil servants (ages 45-68 years) from 20 departments in the London offices, showed that the odds ratios and their 95% confidence intervals for having the metabolic syndrome were 0.52 (0.40-0.67) in vigorous (≥12.5 MET h/wk) activity and 0.78 (0.63-0.96) in moderate (≥24 MET h/wk) activity than in low activity, when controlling for confounders, e.g., age, smoking, alcohol intake, socioeconomic status, and other activity [24]. Katzmarzyk et al. [25] carried out a cohort study of 19 223 men (ages 20-83 years), who were selected randomly from a general population in Canada. Cardiorespiratory fitness was used to classify each subject into two fitness exposure categories. Men with the metabolic syndrome had 1.29-fold higher all-cause mortality and 1.89-fold higher cardiovascular disease (CVD) mortality compared with healthy men. However, the associations were no longer significant after accounting for cardiorespiratory fitness. The relative risks comparing unfit vs. fit men for all-cause mortality was similar in healthy men and men with the metabolic syndrome (2.18 vs. 2.01), whereas the relative risks for CVD mortality for unfit vs. fit men were 3.21 in healthy men and 2.25 in men with the metabolic syndrome. Also, a significant dose-response relationship between cardiorespiratory fitness and mortality was observed in men with the metabolic syndrome. It was concluded that exercise provided a protective effect against the risk of all-cause and CVD mortality in healthy men and men with the metabolic syndrome.

Although there is a consistent inverse association between leisure-time physical activity and metabolic syndrome and its components in men, the association is not as consistent in women. For example, results from the Quebec family study (158 men and 198 women aged 20-60 years) found that cardiorespiratory fitness was independently related to the metabolic syndrome among both men and women. Cardiorespiratory fitness was inversely related to plasma insulin only for men, while cardiorespiratory fitness was only positively related to high-density lipoprotein cholesterol for women. However, cardiorespiratory fitness was not independently related to the components of metabolic syndrome in both sexes after accounting for total and abdominal adiposity [26]. As in another Canadian population-based study (6 406 men and 6 475 women aged 18-64 years) [27], the odds ratios and their 95% confidence intervals for having the metabolic syndrome in physically active men was 0.45 (0.29-0.69) than their physically inactive counterparts, after consideration of covariates including age, smoking, alcohol consumption, and income adequacy. The association disappeared in women after adjusting for the covariates. Sex differences were also found for the association of the metabolic syndrome with leisure-time physical activity in the Fels Longitudinal Study [28], investigating a sample of US young adults (249 women and 237

men aged 18–40 years). Among men, the odds ratios for having the metabolic syndrome risk were independently reduced with increases in both total physical activity (OR = 0.65, 95% CI = 0.47–0.90) and sport activity (OR = 0.40, 95% CI = 0.23–0.70). The components of metabolic syndrome such as abdominal circumference, triglycerides and high-density lipoprotein cholesterol also improved with total and sport physical activity. Among women, the associations of types of physical activity, i.e., leisure, sport, work, and total with the metabolic syndrome were marginal. Only high-density lipoprotein cholesterol was increased by both total physical activity (OR = 0.79, 95% CI = 0.63–0.98) and sport physical activity (OR = 0.54, 95% CI = 0.35–0.84) after controlling for age, smoking and body mass index. These differences may be partly explained by race, age and sex hormone differences, varying patterns of fat distribution, and differences in types and intensity of physical activity.

Two studies have reported an inverse association between leisure-time physical activity and metabolic syndrome in women. A cohort study [29] of a tri-ethnic sample of women (49 African-American, 46 Native-American, and 51 white) aged 40–83 years in the USA demonstrated that the odds ratios and their 95% confidence intervals for having the metabolic syndrome were 0.18 (0.03–0.90) for women in the highest category of moderate-intensity physical activity (≥ 491 MET min/d) compared with those in the lowest category (< 216 MET min/d). The odds ratios for having the metabolic syndrome was 0.07 (0.02–0.35) for women in the highest quartile of maximal treadmill duration (> 16 minutes) compared with women in the lowest quartile (≤ 10 minutes). Although the study population is relatively small, the increased physical activity has important implications in the prevention of metabolic syndrome independently of potential confounding variables. Similar results were found in another study [30] of 7 104 US women, which showed that prevalence of the metabolic syndrome was significantly lower across cardiorespiratory fitness quintiles, with the prevalence ranging from 19.0% in the lowest fit quintile to 2.3% in the highest fit quintile. Also, the prevalence of metabolic syndrome in the different age groups for women who achieved a maximal MET level of 11 or higher was one-third to one-fourth that of women who achieved lower maximal MET levels.

Most studies found that physical activity and fitness was related to the metabolic syndrome in both sexes. An early cohort study [31] of 15 537 men and 3 899 women in the adult US population found that the least-fit men had 3.0- and 10.1-fold higher risk factors for the metabolic clusters (elevated systolic blood pressure, serum triglycerides, fasting blood glucose, and central adiposity) compared with moderately-fit and the most-fit men, respectively. Similarly, the least-fit women had 2.7- and 4.9-fold higher risk factors for the metabolic clusters compared with moderately-fit and the most-fit women, respectively. Data from a cohort of 874 healthy Caucasian participants from the Medical Research Council Ely Study indicated that there was a strong and significant inverse association between physical activity energy expenditure and the metabolic syndrome, while the association between cardiorespiratory fitness and the metabolic syndrome was attenuated after adjusting for age, sex, physical activity, and measurement error. However, cardiorespiratory fitness modified the relationship between physical activity and metabolic syndrome [32]. Thus, prevention of the metabolic syndrome may be most effective in the subset of unfit inactive people.

An Australian study by Dunstan et al. [33] examined the associations of television viewing and physical activity with the metabolic syndrome in 6 241 adults aged ≥ 35 years. They found that the adjusted odds ratios and their 95% confidence intervals for having the metabolic syndrome were 2.07 (1.49–2.88) in women and 1.48 (0.95–2.31) in men who watched TV for > 14 hrs/wk compared with those who watched ≤ 7.0 hrs/wk. Compared

with those who were less active (<2.5 hrs/wk), the odds ratios for having the metabolic syndrome were 0.72 (0.58-0.90) in men and 0.53 (0.38-0.74) in women who were active (\geq 2.5 hrs/wk). Additionally, increased TV viewing time or physical activity was also associated with individual components of the metabolic risk in both sexes. Recently, a Swedish study by Halldin et al. [34] included 3 864 60-year-old men and women in the Stockholm region. The results showed that, compared with the low physical activity group, the odds ratios for having the metabolic syndrome in the high physical activity groups (i.e. intensive regular activity more than 2 times/week, at least 30 min each time) was 0.33 (0.22-0.51) after adjustment for covariates.

Based on a nationally representative population-based sample of US adults aged 20 years and older from the National Health and Nutrition Examination Survey (NHANES), several studies have utilized the NHANES to explore the relationship between leisure-time physical activity and metabolic syndrome. However, the results are inconsistent. Park et al. [35] used a physical activity intensity score to examine the association between physical activity and metabolic syndrome. The score was calculated as a dichotomized variable based on the frequency and intensity of leisure-time physical activity. Participants with the total density rating score > 3.5 were active and those with a total density rating score of ≤ 3.5 were inactive. When compared to the active group, the odds ratios for having the metabolic syndrome were significantly higher (OR = 1.4, 95% CI = 1.0-2.0) among inactive men, but not among inactive women. Similar findings have been reported by Zhu et al. [20], although these participants were grouped into 3 categories: active (score > 15.0), moderately activity (score > 3.6 to 14.9) and inactive (≤ 3.5). Men with the active group were found to be 42% less likely (OR = 0.58, 95% CI = 0.39-0.85) to have the metabolic syndrome compared to those with the inactive group, even after controlling for age, race, education, income levels, and other modifiable factors. In women, the association disappeared after adjusting for the confounders. These finding were also supported by a study reported by DuBose et al. [36]. Leisure-time physical activity was classified as regularly active (≥ 5 d/wk moderate- and/or ≥ 3 d/wk vigorous-intensity physical activity), irregularly active (some physical activity), and inactive (no physical activity). Regularly active represented that the participants met the recommendations of the Centres for Disease Control and Prevention and the American College of Sports Medicine [37]. The results indicated that the odd ratios for having the metabolic syndrome were only higher in men with the irregular activity (OR = 1.52, 95% CI = 1.11-1.23) and inactivity (OR = 1.60, 95% CI = 1.18-1.98) groups than those with the regularly active group after adjustment for age, race, smoking status, and educational attainment.

However, to continue to expand this field, the duration of physical activity, in addition to the frequency and intensity of physical activity, is required to examine a more precise measure of physical activity dose. In the study of examining the interaction between time spent in physical activity and sedentary behaviour on the metabolic syndrome [38], participants were asked about their moderate/vigorous intensity physical activity patterns and moderate intensity household activity, designating these activities in minutes per week ($\text{min}/\text{wk}^{-1}$) based on frequency, duration, and intensity of each activity. These participants were then grouped into three categories: 0, < 150 , and ≥ 150 $\text{min}/\text{wk}^{-1}$ of moderate/vigorous physical activity. However, after adjustment for covariates, the cross-sectional association between physical activity and metabolic syndrome was attenuated for both sexes. In a recent study [39], leisure-time physical activity was measured in two ways: (1) a six-level measure based upon participants reporting no physical activity and quintiles of physical activity (0, $>$

0 to ≤ 156.24 , >156.24 to ≤ 393.10 , >393.10 to ≤ 736.55 , >736.55 to ≤ 1360.15 , and >1360.15 MET·min wk⁻¹) based on the compendium of physical activities for adults [40,41] and (2) a three level categorical measure (inactive, insufficiently active, and met physical activity recommendation) based on the recent physical activity public health recommendation of the American College of Sports Medicine/American Heart Association (ACSM/AHA) [42]. When compared to the no physical activity group, adults with physical activity between 736 and 1360 MET min wk⁻¹ were found to be 35% less likely (OR= 0.65, 95% CI = 0.48–0.88) to have the metabolic syndrome using the National Cholesterol education Program-Adult Treatment Panel III criteria, while adults with physical activity between 393–737 MET min wk⁻¹ were found to be 30% less likely (OR = 0.70, 95% CI = 0.51–0.96) to have the metabolic syndrome using the World Health Organization criteria. Additionally, adults with physical activity met the ACSM/AHA guidelines were found to be 45% (OR = 0.54, 95% CI = 0.44–0.66 for the World Health Organization criteria) and 39% (OR = 0.61, 95% CI = 0.48–0.77 for the American College of Endocrinology/American Association of Clinical Endocrinologists criteria) less likely to have the metabolic syndrome compared with those who were inactive. In addition, cardiorespiratory fitness was first measured by using a submaximal treadmill test in both healthy men (n = 692) and women (n = 608) aged 18–49 years in the 1999-2002 NHANES [43]. Participants were divided into low, moderate, and high fitness tertiles based on the age-adjusted VO_{2max} values. It was showed that the odds ratios for having the metabolic syndrome in men but not women were significantly lower in moderate and high fitness categories compared with the low fitness category, after controlling for confounding variables such as age, ethnicity, poverty-income ratio, alcohol consumption, smoking and fat consumption. These inconsistent findings may be caused by different assessments of physical activity and fitness and different criteria of metabolic syndrome in different age and samples. Also, it remains unknown whether menopausal or hormonal status in women contributes to this observation.

Only two studies have addressed the relationship between muscle strength and metabolic syndrome in adult men. An American study followed 8 570 men aged 20–75 years from 1981 to 1989 [44]. Muscular strength score was computed by combining body weight-adjusted one-repetition maximal measures for leg and bench presses and then divided into strength quartile (Q) from Q1 (low strength) to Q4 (high strength). Men with high levels of muscular strength were found to be less likely to have the metabolic syndrome than those with low strength after adjusting for age and smoking. Similar results were found in an average of 6.7 years follow-up study by Jurca et al. [45]. They stated that men with more muscular strength were also less likely to develop the metabolic syndrome, even after adjusting for smoking, alcohol intake, number of baseline metabolic syndrome risk factors, family history of diabetes, hypertension, and premature coronary disease. However, these associations were partially explained by cardiorespiratory fitness. To our knowledge, only one study has explored the combined effects of muscular strength and aerobic fitness on the metabolic syndrome in both Flemish adult men (n = 571) and women (n = 448) aged 18–75 years [46]. Muscular strength was evaluated by measuring isometric knee extension and flexion peak torque, using a Biodex System Pro 3 dynamometer. The relationship between muscular strength, aerobic fitness and the metabolic syndrome score was analyzed as continuous variables using a multiple linear regression. The risk of metabolic syndrome was inversely associated with muscular strength, independently of aerobic fitness and other confounding factors in women, whereas the association was attenuated when controlling for aerobic

fitness in men. Thus, strength training in addition to aerobic exercise may provide additional effects in reducing the prevalence of metabolic syndrome, particularly for women. These findings are inconsistent that may be partially explained by socio-cultural differences of the samples and the methodological issues including different measures, methods of analysis and sample size.

In summary, these findings imply that leisure-time physical activity, cardiorespiratory fitness and muscular strength may be an important determinant of the overall prevalence of metabolic syndrome independent of several other confounding factors. Accumulating evidence suggests that regular physical activity which increases aerobic capacity and cardiovascular fitness and maintain muscular strength has a beneficial effect on the metabolic syndrome. However, the relationship between physical activity and metabolic syndrome is still somewhat controversial, particularly for women. Such studies have varied in assessments of physical activity (subjective vs. objective), cardiorespiratory fitness (ergometer cycle vs. treadmill tests) and muscular strength (1-repetition maximum vs. isometric dynamometry), as well as criteria or risks to define the metabolic syndrome. In addition, the cross-sectional nature of most of these studies does not allow inference of causality. Further studies examining sex differences in the relation between physical activity and metabolic syndrome that address confounding factors such as menopausal status and concurrent medical conditions are needed. A longitudinal study design is also needed to examine the causal relationship between physical activity and metabolic syndrome.

4. Effect of physical activity and fitness on metabolic syndrome in children and adolescents

The beneficial effect of leisure-time physical activity on the metabolic syndrome in children and adolescents has been assessed within the contemporary reviews [47–50]. Froberg and Andersen [47] have authored a review on the linking physical inactivity and low fitness to metabolic disorders including CVD risk factors and obesity in European children. The authors concluded that there was only weak evidence of the association between physical activity or physical fitness and CVD risk factors in children when risk factors were analyzed isolated, but the clustering of risk factors was strongly associated with low physical activity or physical fitness among children. They also stated that participation in regular physical activity was one of the key determinants of lifestyle-related health. Furthermore, the relationship between aerobic fitness, fatness and the metabolic syndrome in children and adolescents was reviewed [48]. It was concluded that the relationship between fatness and the metabolic syndrome remained significant after controlling for fitness, whereas the relationship between fitness and metabolic syndrome disappeared after controlling for fatness. The author also reviewed four studies [51–54] of the combined influence of fatness and fitness on the metabolic syndrome and concluded that fitness attenuated the metabolic syndrome score among fat children and adolescents when they were cross-tabulated into categories (fat-fit, etc.), it might be possible to involve genetics, adipocytokines and mitochondrial function.

A recent review by Steele et al. [49], outlined the evidence from 6 studies [55–60] on objectively measured physical activity (i.e. accelerometer) and 11 studies [51–54, 59–65] on cardiorespiratory fitness, identifying the influence of physical activity and fitness on the clustered metabolic risk in youth. They concluded that physical activity and fitness were separately and independently related to metabolic risk factors in children and adolescents,

possibly through different causal pathways. Among more recent studies, findings have been mixed. In a population-based sample of 3 193 10- and 15-year-old youth from three European countries (Estonia, Denmark, and Portugal), Ekelund et al. [66] further found that both cardiorespiratory fitness (OR = 0.33, 95% CI = 0.15–0.75) and objectively measured physical activity (OR = 0.40, 95% CI = 0.18–0.88) were significantly and independently associated with being categorized as having the metabolic syndrome. Relatively small increases in physical activity might significantly reduce the risk of metabolic syndrome in healthy youth. Conversely, Martínez-Gómez et al. [67] did not find the same association between physical activity and metabolic syndrome in 202 adolescents (99 girls) aged 13-17 years after controlling for age, sex and maturation status, and suggested that cardiorespiratory fitness appeared to have a pivotal role in the metabolic syndrome and in the association of physical activity with the metabolic risk.

There were only few studies have reported on the effect of diet and physical activity on prevention of the metabolic syndrome in adolescents. For example, Pan and Pratt [68] investigated a sample of 4 450 US adolescents aged 12 to 19 years from the National Health and Nutrition Examination Survey 1999-2002. They reported that although there was not significant relationship between physical activity and the overall prevalence of metabolic syndrome, the differences in some metabolic syndrome components among groups were statistically significant. Adolescents with low physical activity had higher levels of triglycerides and blood pressure than those with moderate or high physical activity. In addition, the prevalence of metabolic syndrome was a 16-fold higher in overweight adolescents (BMI \geq 95th percentile) compared with their normal weight peers (BMI \leq 85th percentile). Higher overall healthy eating index and fruit scores were also associated with lower risk of the metabolic syndrome. The authors concluded that unhealthy lifestyle behaviours might be the major underlying cause for the metabolic syndrome in adolescents. The primary means for preventing the metabolic syndrome was needed to engage adolescents in regular physical activity and healthful dietary practices to prevent excessive weight gain.

However, these studies have not addressed issues specific to population subgroups or intervention-delivery modalities. In a very recent review of the literature on the relationship between physical activity and metabolic syndrome in youth, Brambilla et al. [50] provided an overview of 11 studies [69–79] on physical activity intervention, focusing on a subsample of obese youth and intervention modalities and concluded that the different physical activity programs, relatively short duration and small sample size of these studies likely contributed to the inconsistent results. Although there were some controversies regarding the risk of insulin resistance, fat mass and body mass index for certain subgroups of children and adolescents with obesity, regular vigorous intensity physical activity on blood pressure and lipid levels did much to alleviate concerns that physical activity programs could have positive effect in these metabolic risk parameters. Furthermore, the authors suggested that the effect of low-intensity physical activity (e.g., playing at home, walking to school, dancing, and downstairs) on the metabolic risk in a large sample of overweight and obese children and adolescents should be taken into consideration in future study.

To summarize, several studies have shown that metabolic risk factors are readily detectable in children and adolescents because obesity is closely associated with insulin resistance in youth. It seems that physical activity intervention strategies may be most effective in childhood and adolescence before the development of metabolic syndrome. The main question to be asked is whether the positive effects of physical activity seen in adults will

occur in children and adolescents. Most studies have found that objectively measured physical activity and cardiorespiratory fitness are inversely associated with clustered metabolic risk score in children and adolescents, while some have shown that physical activity in adolescents does not result in significantly reduce the prevalence of metabolic syndrome when cardiorespiratory fitness is adjusted for in the analysis. A question which remains unanswered, however, is how much physical activity is needed to prevent the metabolic syndrome and the diseases with which it is associated. Also, the clustered metabolic risk score has been applied in these studies, but no clear definition of the metabolic syndrome has been formally established for either children or adolescents. Attention to these questions with further research is needed.

5. Early physical activity and fitness as a predictor of metabolic syndrome in adulthood

The mechanism behind the relationship between physical activity in childhood and adolescence and adult risk for the metabolic syndrome has been explored. Referring to the model including three possible paths from childhood physical activity to adulthood health presented by Blair et al. [80], one of the hypothetical paths is a direct connection from physical activity or physical fitness in youth to cardiovascular and metabolic health in adult life. In the Cardiovascular Risk in Young Finns Study [19], 961 participants aged 12-18 years from five cities of Finland were included and followed from 1980 to 1983 and 1986. Physical activity was assessed with a standardized questionnaire and then summed a physical activity index from its intensity, frequency and duration. The results showed that the change in physical activity over 6 years was inversely associated with changes in insulin and triglycerides among boys. Among girls, the change in physical activity did not make any independent contribution to the models for serum lipoproteins. It was concluded that participation in regular leisure-time physical activity should be encouraged among adolescents in order to improve coronary risk profiles. Similar observations have been reported in other European studies. In the Amsterdam Growth and Health Study [81], 181 13-year-old Dutch adolescents were followed over a 15 years. The daily physical activity and fitness (both cardiopulmonary and neuromotor fitness) have been measured with six repeated times during the period. They found that daily physical activity was positively related to high-density lipoprotein cholesterol, and inversely to the total cholesterol/high-density lipoprotein ratio and to the sum of four skinfolds. Additionally, cardiopulmonary fitness was inversely associated with the total cholesterol. Neuromotor fitness was inversely associated with the sum of four skinfolds, and positively to systolic blood pressure. The authors stated that during adolescence and young adulthood both daily physical activity and fitness were related to a healthy coronary heart disease risk profile.

There are two recent studies for extending the Cardiovascular Risk in Young Finns Study. Yang et al. [82] followed 1 319 boys and girls (ages 9-18 years) from five Finnish university towns and their rural surroundings from 1980 to 2001. Leisure-time physical activity was assessed by a short self-report questionnaire. The results indicated that youth physical activity predicted adult physical activity in men ($R^2 = 0.10$) and women ($R^2 = 0.03$), which, in turn, predicted waist circumference in adulthood. Youth body mass index was directly related to waist circumference in adulthood in both sexes. The models were significant explaining 19% of variance of abdominal obesity in men and 13% in women. Also, youth physical activity was indirectly associated with waist circumference in adulthood through

both the maintenance of physical activity in adulthood and reducing body weight in youth. The path from youth physical activity to adult obesity through youth obesity seemed to be stronger than the path through adult physical activity. However, the level of youth physical activity did not predict adult abdominal obesity in either men or women (Figure 1). The authors concluded that the prevalence of abdominal obesity as defined by waist circumference during adulthood was directly related to adult physical activity and youth overall obesity in both sexes. Youth physical activity had an indirect effect on abdominal obesity through both the maintenance of physical activity in adulthood and reduction in body weight in youth. Participation in and maintaining physical activity from youth into adulthood might play an important role in reducing obesity in adulthood.

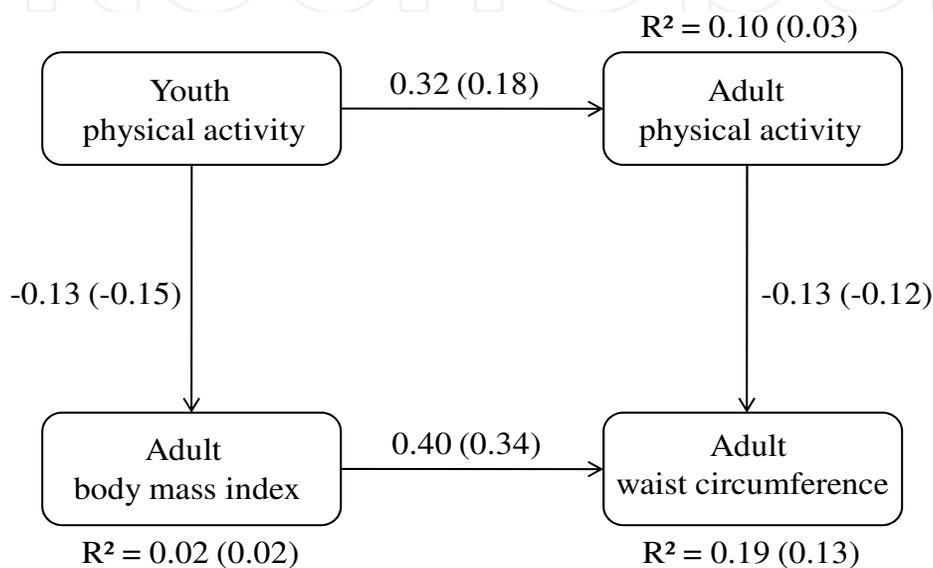


Fig. 1. Estimated parameters (standardized solution) in structural equation for males (females)

In another study by Yang et al. [83], 1 493 Finnish children and adolescents aged 3 to 18 years were followed over a 21-year period. Participation in sport-club training and competitions were assessed by use of a self-report physical activity questionnaire. Participants were divided into athletes and non-athletes at each measurement point (1980 and 1983), and then classified into four groups: persistent athlete, starter, leaver and non-athlete. A mean score of youth sport was assessed by calculating the average of four consecutive measurements (1980-1989). The metabolic syndrome in adulthood was defined as a categorical variable based on the guidelines of the European Group for the Study of Insulin resistance and as a continuous metabolic syndrome risk score by summing the z-scores of individual metabolic variables. The results indicated that the mean score of youth sport across the four time points and covariate variables were simultaneously entered as predictors for the adult metabolic syndrome risk score. Mean youth sport level emerged as a significant predictor of the metabolic syndrome in men ($\beta = -0.149$, $P = 0.001$) and women ($\beta = -0.118$, $P = 0.005$). Furthermore, non-athletic males and females had a significantly higher prevalence of the metabolic syndrome in adulthood than persistent athletes (Table 3). The relationships remained significant after adjustment for age and baseline clustered metabolic risk scores. The odds ratios and 95% confidence intervals for non-athletic males and females were 2.94 (1.01-8.99) and 4.04 (1.18-13.85), respectively. After additional adjustment for adult leisure-time physical activity, the trend of the associations was the same but

significant difference between persistent athletic and non-athletic males disappeared. Those males who dropped out from organized sport during the 3 years had higher prevalence of the metabolic syndrome compared with persistently athletic counterparts. The difference remained significant after adjustment for age, baseline clustered metabolic risk scores and adult leisure-time physical activity (OR = 4.52, 95% CI = 1.29–15.84).

The mechanisms explaining the relationship between sport participation in youth and the prevalence of metabolic syndrome in adulthood are not well understood. One of the more obvious explanations can be that youth sport may reduce the risk of metabolic syndrome in youth, which then tracks into adulthood. However, the explanation is not clear because adjustment for youth clustered metabolic risk does not change the result. In addition, sustained youth sport seems to predict low prevalence of the metabolic syndrome in adulthood 21 years later independently of adult physical activity. It is possible that participation in organized youth sport may establish lifelong habits for good health that in turn reduces risk for the metabolic syndrome. Participation in sustained youth sport may also lead to improved cardiovascular function and physical fitness that carries over into adulthood. Furthermore, children and adolescents who want to maintain their athletic abilities may have better awareness of other health related habits such as diet, smoking and sedentary lifestyle, all of which have been found to be related to risk for the metabolic syndrome. Finally, self-selection and genetic factors shall be taken into account as possible explanations for the direct relationship between youth sport and adult health. Thus, intensive and sustained participation in youth sport may benefit adult cardiovascular health and prevent the development of metabolic syndrome. Organizers of youth sport may have a significant impact on public health by paying attention to the factors that increase adherence in youth sport.

Group	Unadjusted OR (CI)		Adjusted OR (CI) ²⁾		Adjusted OR (CI) ³⁾	
Boys						
Persistent athlete	1.00		1.00		1.00	
Starter	1.62	0.45 – 5.80	1.49	0.39 – 5.71	1.55	0.41 – 5.85
Leaver	4.55	1.39 – 14.87*	4.70	1.31 – 16.91*	4.52	1.29 – 15.84*
Non-athlete	3.06	1.08 – 8.64*	2.94	1.01 – 8.99*	2.72	0.90 – 8.17
Girls						
Persistent athlete	1.00		1.00		1.00	
Starter	1.67	0.38 – 7.27	1.63	0.35 – 7.64	1.66	0.36 – 7.69
Leaver	2.24	0.60 – 8.35	1.98	0.47 – 8.30	1.57	0.38 – 6.44
Non-athlete	3.54	1.08 – 11.55*	4.04	1.18 – 13.85*	3.46	1.03 – 11.66*

¹⁾ 3-year follow-up youth sport: persistently athlete (did between 1980 and 1983); starter (did not in 1980 but did in 1983); leaver (did in 1980 but did not in 1983); and non-athlete (did in neither 1980 nor 1983).

²⁾ Adjusted for baseline age, smoking, total caloric intake and baseline-clustered risk for metabolic syndrome.

³⁾ Additionally adjusted for adult leisure-time physical activity. * $p < 0.05$.

Table 3. Odds ratios for the prevalence of metabolic syndrome (European Group for the Study of Insulin Resistance) according to organized youth sport ¹⁾ over 3 years in boys and girls

Contrary to the expected beneficial effect, no association between the level of physical activity and the risk of metabolic syndrome was found. In the Leuven Longitudinal Study on Lifestyle, Fitness and Health [84], 166 Belgian adolescent boys aged 13–18 years were

followed over a 28-year period. Physical activity was assessed by means of a sports participation inventory in youth and the Tecumseh community health study questionnaire in adulthood. The results found that sports participation during adolescence was not related to levels of cardiovascular risk factors at 40 years of age. In the Danish Youth and Sport Study [85], 101 adolescents aged 15–19 years were followed over an 8-year period. Physical activity was assessed by a questionnaire including the number of hours per week of sports participation and physical education lessons. Physical fitness in terms of aerobic fitness was calculated as VO_{2max} relative to body weight (ml/min/kg). It was shown that the relationships between the absolute levels of physical fitness and activity in adolescence and the subsequent level of CVD risk factors were generally weak. However, the changes in physical fitness and physical activity were related to the absolute levels of CVD risk factors in young adulthood, especially in men. A subsequent study conducted by the same investigators [86] reported similar results when a physical activity index was constructed from the intensity and duration of the organized and unorganized sports activities. The results showed that the youth sports activities and fitness were not associated with clustered risk in adulthood. The lack of significant associations could be due to methodological limitations such as small samples and assessment of physical activity based on self-reported minutes spent on sports activities rather than objective measure to physical activity. Moreover, future study is indicated in distinguishing between active and inactive on the adulthood risk of developing the metabolic syndrome. Future research is also need to develop and evaluate objective measures of physical activity (e.g., pedometers, accelerometers) in youth, define and measure the criteria of metabolic syndrome and clarify whether long-lasting changes in physical activity decrease the metabolic risk for different lifespan.

6. Effect of change in physical activity and fitness on metabolic syndrome in adulthood

According to the model [80], the most probable path is from childhood physical activity to adult physical activity and further to adult metabolic health. This supported by the studies on tracking of physical activity [87–90], and also studies on the relationship between physical activity and metabolic syndrome in either youth or adults as has just been mentioned above. Another potential path is physical activity in youth through youth clustered metabolic risk to adult metabolic syndrome. This path is supported by the finding that physical activity and physical fitness correlate negatively with the metabolic risk in youth [49]. Further, metabolic risk variables, especially obesity, likely track rather well from childhood to adulthood [82,91]. Only a few prospective population-based studies have reported long-term physical activity in predicting the prevalence of metabolic syndrome over time and especially of changes in physical activity in association with adulthood metabolic syndrome.

Laaksonen et al. [92] followed a cohort of 612 middle-aged men in the Kuopio Ischemic Heart Disease Risk Factor Study over a 4-year follow-up period. Leisure-time physical activity was measured by a questionnaire with the dose calculated as MET-minutes per week. Physical activity was then grouped into three levels: low-intensity (< 4.5 METs-min/wk), moderate- and high intensity (≥ 4.5 METs-min/wk) and high-intensity physical activity (≥ 7.5 METs-min/wk). Cardiorespiratory fitness (VO_{2max} , ml·kg⁻¹·min⁻¹) was divided into three levels: low (≤ 28.9), moderate (29.0–35.6) and high (≥ 35.7). Men with moderate and vigorous physical activity were significant lower prevalence of the metabolic syndrome than those with low physical activity. The odds ratios were 0.60 (0.37–0.99) for physical activity ≥ 4.5 METs (>3 h/wk vs. ≤ 60 min/wk) and 0.48 (0.29–0.77) for physical activity ≥ 7.5

METs after adjustment for major confounding variables (age, body mass index, smoking, alcohol, and socioeconomic status) or potentially mediating variables (insulin, glucose, lipids, and blood pressure), especially in high-risk men. Vigorous physical activity had an even stronger inverse association, particularly in unfit men. Men in the highest tertile of cardiorespiratory fitness were 75% less likely to develop the metabolic syndrome than men in the lowest tertile of cardiorespiratory fitness after adjustment for major confounders, but the association was attenuated after adjustment for possible mediating variables. It was included that physical activity and cardiorespiratory fitness predicted directly or indirectly the development of metabolic syndrome.

A randomized controlled trial was used to investigate the effectiveness of supervised aerobic exercise training in 105 participants with the metabolic syndrome before and after 20 weeks [93]. 30.5% (32 participants) of the participants were no longer classified as having the metabolic syndrome following exposure to a standardized 20-week exercise program. It was suggested that aerobic exercise training showed prolonged vigorous exercise programs and reduced substantially in those with the metabolic syndrome. Although limited by lack of a control group, this study supported that the effectiveness of aerobic exercise training could be useful as a treatment strategy in prevention of the metabolic syndrome. In their further study of the impact of cardiorespiratory fitness on the risk of metabolic syndrome, obesity and mortality among 19 173 American men aged 20–83 years, Katzmarzyk et al. [94] reported that the odds ratios and their 95% confidence intervals for having risks of all-cause mortality were 1.11 (0.75-1.17) in normal weight, 1.09 (0.82-1.47) in overweight, and 1.55 (1.14-2.11) in obese men with the metabolic syndrome, compared with normal weight healthy men. The corresponding risks for cardiovascular disease mortality were 2.06 (0.92-4.63) in normal weight, 1.80 (1.10-2.97) in overweight, and 2.83 (1.70-4.72) in obese men with the metabolic syndrome, compared with normal weight healthy men. However, the risks of all-cause mortality associated with obesity and metabolic syndrome were no longer significant after adjustment for cardiorespiratory fitness, which suggested that these risks were largely explained by overall physical fitness levels.

In the Medical Research Council Ely Study [95], 605 (249 males) middle-aged adults in England were followed over the past 5.6 years. Physical activity energy expenditure was measured objectively by individually calibrated heart rate against energy expenditure and was then divided into quartiles: < 44 kJ/kgFFM/d, 44-70 kJ/kgFFM/d, 71-100 kJ/kgFFM/d, and > 100 kJ/kgFFM/d. Aerobic fitness was predicted from a submaximal exercise stress test. Physical activity energy expenditure predicted progression toward the metabolic syndrome after adjusting for sex, baseline age, smoking, socioeconomic status, follow-up time, and baseline phenotypes. The associations remained significant after additional adjustment for aerobic fitness. While the relationship between aerobic fitness and metabolic syndrome was attenuated after adjusting for physical activity. In a cohort of the Oslo study, Holme et al. [96] followed 6 410 Norwegian middle-aged men from 1972/3 to 2000 in the city of Oslo. Leisure-time physical activity was measured by a questionnaire to classify men into four groups as follows: sedentary/light (usually reading, watching television or other sedentary occupations at leisure), moderate (walking, bicycling or other forms of physical activity including walking or bicycling to and from the place of work and a Sunday walk totalling at least four hours a week), moderately vigorous (exercise, sports, heavy gardening and similar activities totalling at least 4 hours a week), and vigorous (hard training or competition sports regularly several times a week). Physical activity was a significant predictor of the prevalence of metabolic syndrome (OR = 0.65, 95%CI = 0.54-0.80)

and diabetes (OR = 0.68, 95%CI = 0.52–0.91) over 28 years when adjusted for age and educational attendance. However, these associations were markedly attenuated when additionally adjusted for baseline clustered metabolic risks.

Yang et al. [97] followed six cohorts of 2 060 (961 males) young adults aged 24–39 years in the Young Finns Study. Leisure-time physical activity was assessed using a self-report questionnaire completed in connection with a medical examination at two consecutive measurements in 1992 and 2001. By summing the physical activity items, a physical activity index was formed for both measurement points according to which the participants were divided into tracking groups: persistently active, increasingly active, decreasingly active, and persistently inactive. The prevalence of the metabolic syndrome on all three definitions was significantly lower in men and women who were persistently active during the 9 yr of follow-up compared with persistently inactive ones. In men, the odds ratios and their 95% confidence intervals were 0.23 (0.11–0.49) for the European Group for the Study of Insulin Resistance (EGIR) criteria, 0.54 (0.31–0.93) for the National Cholesterol Education Program-Adult Treatment Panel III (NCEP) criteria, and 0.49 (0.29–0.83) for the International Diabetes Federation (IDF) criteria. In women, the odds ratios were 0.33 (0.12–0.94) for EGIR, 0.21 (0.06–0.67) for NCEP, and 0.27 (0.11–0.63) for IDF. Also, women who were increasingly active were less likely on all definitions to have the metabolic syndrome than their persistently inactive counterparts. The associations remained significant for EGIR (OR = 0.28, 95% CI = 0.09–0.92), NCEP (OR = 0.22, 95% CI = 0.07–0.73), and IDF (OR = 0.42, 95% CI = 0.19–0.94). All of these associations remained significant after adjustment for potential confounders such as age, smoking and education (Table 4). The authors concluded that

Group	EGIR Adjusted OR (CI) ²⁾		NCEP-ATP III Adjusted OR (CI)		IDF Adjusted OR (CI)	
Men						
Persistently inactive	1.00		1.00		1.00	
Decreasingly active	0.69	0.41 – 1.15	0.99	0.62 – 1.57	1.07	0.69 – 1.65
Increasingly active	0.73	0.30 – 1.79	0.58	0.22 – 1.52	0.48	0.19 – 1.27
Persistently active	0.23	0.11 – 0.49***	0.54	0.31 – 0.93*	0.49	0.29 – 0.83**
Women						
Persistently inactive	1.00		1.00		1.00	
Decreasingly active	0.68	0.35 – 1.34	0.65	0.35 – 1.21	0.59	0.33 – 1.05
Increasingly active	0.28	0.09 – 0.92*	0.22	0.07 – 0.73*	0.42	0.19 – 0.94*
Persistently active	0.33	0.12 – 0.94*	0.21	0.06 – 0.67**	0.27	0.11 – 0.63**

EGIR, European Group for the Study of Insulin Resistance; NCEP-ATP III, National Cholesterol education Program-Adult Treatment Panel III; IDF, International Diabetes Federation.

¹⁾Physical activity groups: persistently inactive (inactive both in 1992 and 2001); decreasingly active (change 1992–2001 from active to inactive); increasingly active (change 1992–2001 from inactive to active); and persistently active (active both 1992 and 2001).

²⁾ Adjusted for age, smoking and education. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Adjusted odds ratios for three definitions of metabolic syndrome according to change in physical activity groups ¹⁾ over a 9-yr period

maintaining a high level of physical activity across the life span might decrease the prevalence of the metabolic syndrome not only in the short term but also in the long term. Individuals should be encouraged to participate in regular physical activity as early as possible to prevent the risk of developing the metabolic syndrome and related adult-onset diabetes and cardiovascular diseases.

7. Conclusion

Outlined in this chapter is a brief overview of leisure-time physical activity, cardiorespiratory fitness and muscular strength which focus is on prevention and intervention of the prevalence of the metabolic syndrome in youth and adulthood. In addition, there is a brief summarizes on maintaining regular physical activity and aerobic exercise over time focused on the metabolic syndrome in adulthood.

It is worth highlighting that regular leisure-time physical activity, endurance training, and strength training are critically important for prevention of the metabolic syndrome and its components in both early life and later life. Evidence is beginning to accumulate in the epidemiological literature which suggests that participation in regular aerobic and strength exercises, particularly when combined with moderate- or vigorous-intensity activity may alter all metabolic risk factors. Leisure-time physical activity is an effective intervention or modulation to improve cardiovascular functional capacity and prevent or delay the development of metabolic syndrome, which in turn maintains health status and reduces the incidence of diabetes and cardiovascular diseases. According to the recommendations of the American College of Sports medicine and the American Heart Association, all adults shall participate in accumulated moderate-intensity physical activity during leisure time for a minimum of 30 minutes or more on 5 days per week or vigorous intensity activity for a minimum of 20 minutes on 3 days per week [42]. It may be that the combination of reductions in energy intake and increases in energy expenditure, through structured exercise and other forms of physical activity, is one of the most effective way to prevent or delay the development of metabolic syndrome over time. This chapter focuses mainly on physical activity and aerobic exercise during leisure time related the prevalence of metabolic syndrome, however there is limited literature relating to specific sport activities, work-related physical activity, commuting physical activity and household physical activity. Emphasis will be placed on the impact of these activities in the future.

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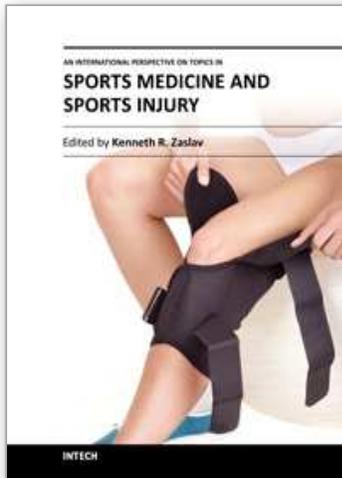
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For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

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Phone: +86-21-62489820
Fax: +86-21-62489821

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