

## Long-term outcomes of sports on health status: a mini review

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### Abstract

This article represents a review of the existing literature on possible long-term effects of sport participation at high-level on health. Search of databases was performed through Web of Science and Science Direct including following keywords: metabolic risk factor/syndrome, diabetes mellitus and cardiovascular health. Former athletes tend to adopt healthier lifestyles, which may give them an advantage in relation to risk factors taking into account metabolic risk factor/syndrome, diabetes mellitus and cardiovascular health. Health benefits of physical activities, moreover, depends of engagement at recommended levels, even in subjects who have never been athletes.

**Keywords** former athletes • physical activity • metabolic syndrome • diabetes mellitus • cardiovascular health

### Introduction

It is probable that physical activity in childhood and youth has a positive impact on participation at a later age. Physical exercise for the elderly seems to play a particularly important role, especially in the prevention of slowly progressing functional deficiencies. According to Backmand et al. (2006), increasing physical exercise is associated with improved physical daily ability. Engaging in a phy-

sically active life-style early in life, as exemplified by elite athletes, can also maintain psychological wellbeing later in life.

Former athlete, especially at an elite level according to Batista & Soares (2014), is associated with a decreased likelihood for the prevalence of major chronic disease risk factors. Physical exercise influences not only physical fitness, but also psychological and social ability (Backmand et al., 2006).

Functional abilities in later life may be compromised due to negative consequences of injuries sustained during sports (Maffulli et al., 2010; Simon & Docherty, 2017). Linger in adulthood which may have been caused by the high level athletic demands possibly make participants unable to stay active as they are getting older, and in such a way may impair their health-related life quality (Simon & Docherty, 2014). Highly competitive athletes train for many years to reach the elite level, and when the high-level regular training stimulus is removed, they get affected physiologically and psychologically (Simon & Docherty, 2014).

Physical Activities, according to the Compendium (Ainsworth et al., 2011), based on the intensity of exercise performed between each sport, with their respective metabolic equivalent (MET) intensity levels, athletes could be classified by the various sports they used to participate in. Sports categories were defined as (Pate et al., 1995): light sports (<3.0 METs or <4 kcal/min; walking, golf, bowling) moderate (3-6 METs or 4-7 kcal/min; volleyball, gymnastics, archery, field events – throwing and jumping) and vigorous (>6 METs or >7 kcal/min; judo, canoeing/rowing, sprint running, middle- and long-distance running,

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triathlon, decathlon, swimming, basketball, handball, and soccer).

According to the adult recommendations from the American Heart Association and the American College of Sports Medicine (Haskell et al., 2007), subjects are considered to have lower physical activity than recommended (Lower PAR) if after career termination they engage in less than 30 minutes a day on 5 days a week of aerobic, moderate-intensity, or less than 20 minutes a day on 3 days a week of vigorous-intensity aerobic activity. If engagement is at least 30 min a day on 5 days a week of moderate-intensity aerobic, or 20 min a day on 3 days a week of vigorous-intensity aerobic activity, we consider subjects as meeting recommendations of physical activity (Meet PAR).

This article represents a review of the existing literature on possible long-term effects of sport participation at high-level on health.

## Method

Search of databases was performed through Web of Science and Science Direct including following key words: former athletes, metabolic risk factor/syndrome, cardiovascular health and diabetes mellitus. Studies were included if they (i) were original research; (ii) evaluated the health status in terms of abovementioned key words (iii) retired athletes as the study subjects. Exclusion criteria for choosing studies for this review was if they were published in other language than English, book chapters, thesis or dissertations, case reports, review articles, conference abstracts, editorials commentaries or expert opinion.

## Results

Metabolic syndrome (MetSyn) is a group of metabolic risk factors that can directly develop cardiovascular disease (Expert Panel on Detection, 2001), and also increase the risk for developing type II diabetes mellitus (Grundy et al., 2005). Physical Activity Guidelines for Americans (U.S. Department of Health and Human Services, 2008) emphasize the association of physical activity with numerous health benefits, such as lower incidence of CVD (Kohl, 2001), and diabetes mellitus type 2 (Kelley & Goodpaster, 2001). This interaction partly occurs through components of the metabolic syndrome (Laaksonen et al., 2002) such as weight control and

improved functioning of the cardiovascular system. Also, several CVD risk factors are favorably modified by long-term exercise, including obesity, glucose tolerance, blood pressure and blood lipids (Unt et al., 2008). Evidence emphasizes that lower cardiovascular mortality is more strongly associated with vigorous exercise than the less intense physical activities (Lee & Paffenbarger, 2000). Former elite athletes are represented as distinct group of individuals who have exercised with heavy training loads for several years (Pihl et al., 2003) and during their sports careers regularly participate in competitions different from the general population (Pihl et al., 1998). Suggested by the epidemiological studies, they have a lower prevalence of diabetes, hypertension, and CVD (Kujala et al., 1994), which can be explained because they tend to adopt healthier lifestyles and to be more physically active (Backmand et al., 2010). Nevertheless, suggested by other studies, regardless of reached competitive level or actual engagement levels of physical activity, former athletes are likely to keep their fitness advantage over nonathletes well into middle age (Saltin & Grimby, 1968; Paffenbarger et al., 1984), which is associated to the prevalence of the syndrome inversely (Ford and Li, 2006). In another research, it has been concluded that pituitary dysfunction and MetS are relatively common in retired professional football players and may be significant contributors to their poor quality of life (Kelly et al., 2014).

Metabolic syndrome is defined according to criteria of the International Diabetes Federation: waist circumference  $\geq 94$  cm plus any two of the following factors: (a) triglycerides  $\geq 1.7$  mmol/l or specific treatment for this; (b) HDL  $< 1.03$  mmol/l or specific treatment for this; (c) systolic BP  $\geq 130$  or diastolic BP  $\geq 85$  mm Hg or treatment of previously diagnosed hypertension; fasting plasma glucose  $\geq 5.6$  mmol/l or previously diagnosed type II diabetes (Alberti et al., 2006).

Former athletes use healthier lifestyles, and that may give them an advantage regarding the risk factors that describe the syndrome (Table 1). In addition, recommended levels of physical activity engagement seems to play an important role in the association with metabolic syndrome, even in those subjects who have never played any competitive sport (Batista & Soares, 2013).

Male former top-level athletes with a history of vigorous physical activity had a lower prevalence of type 2 diabetes than the matched controls, according to findings. It is found that the lowest prevalence of

type 2 diabetes had those participants with the most LTPA in later life (Laine et al., 2014).

**Table 1.** Health status of former athletes in terms of metabolic syndrome

Aim	Subjects	Sex	Test/measure	Results
Batista & Soares, 2013				
Whether former athletes are better protected against MetSyn and if this hypothetical protection is dependent on sex, career, or later lifestyle?	Form el ath	M	Demographic info	No significant differences in the likelihood of MetSyn among non-athletes, former elite and non-elite athletes. Also, significant association of sex and previous sport intensity with the syndrome was not revealed. Although, both non-elite athletes (OR 0.50, $p = 0.044$ ) and former elite athletes [odds ratio (OR) 0.20, $p = 0.020$ ] who after career cessation engaged in certain amount of physical activity according to recommendations, showed less probability for the MetSyn.
	225	+	Behavioral and biological characteristics	
	Form nonel athl	F	Physical and biochemical measurements	
	168			
	Controls			
	98			
Batista & Soares, 2014				
Whether the prevalence of behavioral and biological risk factors of former elite athletes (both men and women), differed from nonelite athletes and nonathletes?	Form el ath	M	Demographic info	Besides alcohol consumption, former elite athletes had minimum 70% less probability for the other behavioral risk factors than nonathletes. Speaking of biological factors, minor differences exist in being overweight/obese, and only among female elite athletes appeared significant odds ratio (0.09, $p < 0.001$ ) in comparison to nonathletes.
	225	+	Behavioral and biological characteristics	
	Form nonel athl	F	Physical and biochemical measurements	
	168			
	Controls			
	98			
Kelly et al., 2014				
The association between mild TBI (mTBI) and pituitary and metabolic function in retired football players?	Form NFL athl	M	Demographic info	MetS was present in 50% of subjects.
	68		Behavioral and biological characteristics	Pituitary dysfunction and MetS are relatively common in retired professional football players and may be significant contributors to their poor QoL.
			Physical and biochemical measurements	
Laine et al., 2014				

Prevalence of impaired glucose regulation in male Finnish former elite athletes and age- and area- matched controls?	Form Athl 392 (72.7±6.1) Controls 207 (71.6±5.6) Σ=599	M	Oral Glucose Tolerance Test  Anthropometric data  Assessment of smoking habits  Assessment of LTPA	Compared with the controls, the former elite athletes had a significantly lower risk of type 2 diabetes (OR 0.72, 95% CI 0.53, 0.98). The risk of type 2 diabetes decreased with increased LTPA volume (OR 0.98, 95% CI 0.97, 0.99 per 1MET-h/week). The former elite athletes also had a significantly lower risk of impaired glucose tolerance (IGT) than the controls (OR 0.58, 95% CI 0.38, 0.87). Former elite athletes were better protected in later life from both IGT and type 2 diabetes. Current LTPA volume was inversely related with type 2 diabetes prevalence.
Laine et al., 2016				
Former male elite athletes have lower body fat percentage, lower risk for MS, and NAFLD in late life independent of the volume of current LTPA?	Form Athl 392 (72.7±6.1) Controls 207 (71.6±5.6) Σ=599	M	Anthropometric data  Blood pressure  Blood sampling  Assessment of MS  NAFLD  LTPA	Compared with the controls, the former athletes had lower body fat percentage (24.8% vs 26.0%, P = 0.021), lower risk for NAFLD (OR 0.61, 95% CI 0.42–0.88) and for MS (OR 0.57, 95% (CI) 0.40–0.81]. High volume of current leisure time physical activity (LTPA) was associated with lower body fat percentage (P for trend < 0.001). The risk of MS and NAFLD decreased as current volume of LTPA increased 1 MET h/week (OR 0.99, 95% CI 0.98–0.99 and OR 0.97, 95% CI 0.96–0.98, respectively).

Overweight and obesity, and the accumulation of metabolically detrimental visceral adipose tissue might be protected by long-term physical activity which plays an important role (Aadahl et al., 2007; Vissers et al., 2013; Philipsen et al., 2015). Further, several studies have shown positive effects of physical activity on glucose metabolism and BP (Thune et al., 1998; Hu et al., 2003; Hu et al., 2014). Former male elite athletes with a history of vigorous physical activity have lower body fat percentage, lower risk for metabolic syndrome, and nonalcoholic fatty liver disease than the age-matched controls in late life. Further, also, current degree of physical activity has a major influence. Those with high volume of LTPA in late life have lower body fat percentage, lower risk for MS, and NAFLD. However, a history of vigorous physical activity in young adulthood is associated with MS independently, present exercise levels and volume of LTPA are certainly of importance (Laine et al., 2016).

Observations in previous study have shown that a career as a top-level athlete is related with a low prevalence of diabetes (Sarna et al., 1997). It seems that costs of diabetes medication in later life are being reduced by having a career as former sprint, endurance, team game athlete or a jumper (Laine et al., 2017).

### Diabetes mellitus

Diabetes is continuing to be an international rising health burden. The estimate for 2010 of 285 million adults with diabetes is 67% higher than the 2004 published estimate for the year 2000, and 2030 estimate of 439 million is 20% higher than the same study's estimate for 2030 (Shaw et al., 2010).

Insulin-dependent diabetes is associated with paternal diabetes and with diabetes in siblings, and non-insulin diabetes is associated with maternal diabetes. Former athletes have lower risk of NIDD compared to nonathletes, and such a lower risk showed consistency

that physical activity appears to be protective for NIDD (Table 2). Non – insulin dependent diabetes risk is reduced by modifiable behavioral practices such as weight control (i.e., optimal BMI) and physical activity (Wyshak, 2002).

According to Wyshak (2002) physician-diagnosed diabetes was reported by 1.3% of the entire group of

college graduates. In former college athletes, diabetes was reported by 0.9% and by 1.7% in non-athletes. These percentages are considerably lower than the 3.2% (about 8.5 million persons) who, in 1996, reported they had diabetes (Surgeon General Surveillance Report, 1999).

**Table 2.** Diabetes mellitus in former athletes

Aim	Subjects	Sex	Test/measure	Results
Laine et al., 2017				
Whether vigorous physical activity during young adulthood is associated with costs of diabetes medication in later life?	Form Athl 1314  Controls 860  $\Sigma=2174$	M	Diabetes medications data  According to the costs of medications, medications were divided into two classes: insulin (ATC-code A10A) and other diabetes drugs (ATC-codes A10B and A10X)	Among former endurance athletes (mean 81 € [95% CI 33–151 €]) and mixed group athletes (mean 272 € [95% CI 181–388€]) the total cost of diabetes medication per person a year was significantly lower compared with the controls (mean 376 € [95% CI 284–485 €]), ( $p=0.001$ and $p=0.045$ , respectively).  insulin was used by 0.4% in former endurance athletes while in the control group it was used by 5.2% ( $p=0.018$ )
Wyshak, 2002				
Risk factors for diabetes in female former college athletes compared with nonathletes?	Form Athl 1945  Controls 1995	F	Questions on health, medical history, behavioral practices, and family history	1.3% of the entire group of college graduates reported physician-diagnosed diabetes, 1.7% of the nonathletes and 0.9% of the former athletes. Risk of NIDD was significantly lower in former athletes, with an odds ratio adjusted for age (OR) of 0.41, 95% confidence level (CL) 0.2, 0.9. IDD was related to the history of diabetes in siblings (OR 5 6.7, 95% CL 1.5, 30.1) and also to the history of paternal diabetes (OR 5 4.7, 95% CL 1.5, 14.9). NIDD was related to a history of maternal diabetes (OR 5 8.0, 95% CL 3.6, 17.8). There was no relation between behavioral factors and IDD, but behavioral factors were inversely related to NIDD. For being an athlete the odds ratio (OR) was 0.4, 95% CL 0.2, 0.9 ; for current regular exercise, OR 5 0.4, 95% CL 0.2, 0.9; low body mass index (BMI) compared to high BMI, OR 5 0.2, 95% CL 0.05, 0.60.

## Cardiovascular health

A constellation of functional, structural, and electric cardiac adaptations refers to as athlete's heart and can occur as a result of regular intensive exercise over an extended period of time (Spirito et al., 1994; Utomi et

al., 2013). The type and extent of these cardiac adaptations, according to the Morganroth theory, are dependent on the pursued sport (Morganroth et al., 1975). Eccentric left ventricular hypertrophy, normal diastolic function and 4-chamber enlargement occur due to endurance training, characterized by extended

increases in cardiac output. Conversely, strength training, characterized by brief but dramatic increases in afterload, is proposed to result in concentric left ventricular hypertrophy. Although this adaptive response has not been consistently shown in strength athletes, developing concentric hypertrophy have been shown by American Style football players (Utomi et al., 2013; Weiner et al., 2013). Hypothetically, enlargement of the aorta would be expected as a result of these hemodynamic loads and indeed, changes have been demonstrated in the elastic properties of the aorta in elite, top level athletes (D'Andrea et al., 2012). Although elite athletes have remarkably larger ascending aortic dimensions than the other population, indicated by studies (D'Andrea et al., 2012; Iskandar & Thompson, 2013), these changes still fall within established limits for the general population and aren't quite large (Boraita et al., 2016). Very few athletes (1.0%–1.8%) have an ascending aorta measuring >40 mm (Kinoshita et al., 2000; D'Andrea et al., 2012; Boraita et al., 2016) according to arbitrary cut off used to define aortic enlargement in practice guidelines and clinically.

Being a former top-level athlete is related with a larger ascending aorta independent of size, race, age, history of diabetes mellitus or hypertension, blood pressure, current smoking status, or lipid profile (Gentry et al., 2017). As defined by an aorta dimension >40mm, there is a 2-fold higher risk of having aortic dilatation in former NFL athletes even when adjustments for abovementioned parameters are made (Hiratzka et al., 2010; Iskander & Thompson, 2013; Braverman et al., 2015). When considering player position of NFL players, aortic dilatation prediction is primarily led by

lineman in contrary to non-lineman (Gentry et al., 2017).

The risk for levels of selected coronary artery disease risk factors or coronary artery disease risk factors of former athletes after career cessation from active sports are more associated with the present-time physical activity i.e., coronary artery disease risk is lowered by higher total physical activity (Gentry et al., 2017). The former athletes, who are maintaining physical conditioning following retirement (the active older athletes) are showing higher total physical activity levels and have a lower risk of coronary artery disease compared to sedentary older athletes and nonathletes. However, the former athletes, who following retirement have more sedentary lifestyles, are found to be at greater risk for coronary artery disease. The risk for coronary artery disease in terms of plasma lipids in this former group of athletes (sedentary older athletes) is found to be even greater than that of sedentary age-matched individuals (sedentary older non-athletes) who have no athletic training history. In terms of anthropometric obesity parameters, blood pressure and plasma lipids, there is a greater risk of coronary artery disease in former athletes who are leading a sedentary lifestyle compared to their more active counterparts (Kumar Dey et al., 2002).

Compared to the area and age matched controls, former endurance athletes have lower prevalence of hypertension, smoke less, and have higher intensity and volume of LTPA (Sarna et al., 1997). Even though the previous medical history may play an important role, vigorous LTPA during the entire lifetime relates good with cardiovascular health (Johansson et al., 2016).

**Table 3.** Cardiovascular health of former athletes

Aim	Subjects	Sex	Test/measure	Results
Kumar Dey et al., 2002				
Effects of present-time physical activity on selected CAD (coronary artery disease) risk factors in older former athletes compared with older non-athletes of the same age	Active older athl	M	Anthropometric obesity parameters	There was significant difference between the groups in the selected CAD risk factors. The SOD had significantly higher mean values in weight, BMI, body fat percentage, total cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides and ratio of total cholesterol to highdensity lipoprotein cholesterol (total C/HDLC) than that of AOA and SONa. A reverse trend was observed in the case of HDL cholesterol. On the other hand, the presently AOA had significantly favourable levels of most of the selected CAD risk factors than the SOA and SONa. There was a significant negative association of the present-day total physical activity with total cholesterol, triglycerides, ratio of total cholesterol to HDL, LDL cholesterol, resting systolic blood pressure when controlling for the effects of age, body mass index and body fat percentages.
	52		Blood lipids	
	Sedentary older athl		Blood pressure	
	54		VO2 max	
	Sedentary older non athl		Questionnaire-concerning the total present-time physical activity	
	56			
Kettunen et al., 2015				
Life expectancy and mortality among former elite athletes and controls	Form	M	HR analysis of cause-specific deaths	Median life expectancy in the endurance sports (79.1 years, 95% CI 76.6 to 80.6) and team sports (78.8, 78.1 to 79.8) was higher compared to controls (72.9, 71.8 to 74.3). Risk for total mortality adjusted for birth cohort and socioeconomic status was lower in the team (0.80, 0.72 to 0.89) and endurance (HR 0.70, 95% CI 0.61 to 0.79) sports athletes, and slightly lower in the power sports athletes (0.93, 0.85 to 1.03) compared to controls. Heart rate (HR) for ischemic heart disease mortality was lower in the team (0.73, 0.60 to 0.89) and in the endurance (0.68, 0.54 to 0.86) sports athletes. Heart rate for stroke mortality was 0.59 (0.40 to 0.88) in the team and 0.52 (0.33 to 0.83) in the endurance sports athletes. The risk for smoking-related cancer mortality was lower in the power sports (0.40, 0.25 to 0.66) and in the endurance (HR 0.20, 0.08 to 0.47) sports athletes compared to controls. The power sports athletes, especially boxers, had increased risk for dementia mortality (HR 4.20, 2.30 to 7.81).
	Athl			
	2363			
	Controls			
	1657			
Johansson et al., 2016				
Effects of previous and current physical activity on cardiovascular health?	Form	M	Body mass	Athletes performing vigorous LTPA had more elastic arteries than athletes performing moderately or no LTPA. Vigorous LTPA during the entire lifetime relates good to cardiovascular health, even though the previous medical history can play an important role.
	Athl		index (BMI),	
	99		fasting serum glucose, blood pressure, lipids,	
	Controls		and	
	49			

			cardiac and carotid artery ultrasonography	
			structure and function	
Gentry et al., 2017				
Evaluation ascending aortic dimensions in former elite athletes and comparison to a similar age and ethnic control group.	Form	M	Height and weight	When compared with the controls mean ascending aortic diameter was significantly larger in retired NFL athletes (38±5 versus 34±4 mm; P<0.0001).
	Athl		4 BP readings	
	206		CT scan for assessment of coronary calcium burden	Larger aortic area indexed to height, after adjustment, is predicted by former NFL status (standardized $\beta$ coefficient of 0.2; P<0.001)
	Controls		Cardiovascular history questionnaire	
	759			

Hazard ratios for ischemic heart disease mortality and for stroke mortality are lower in endurance and team sports athletes than in controls. Mortality for dementia is increased in power sports athletes. Comparing to men who were healthy as young adults, elite athletes have higher life expectancy of 5-6 years (Kettunen et al., 2015).

## Conclusion

It has been shown that male former athletes are more physically active than age – matched control individuals. More than 60% of former elite male athletes are engaged in competitive sports or leisure time physical activity throughout their adult life after retirement (Batista & Soares, 2014). This behaviour is also common in female former elite athletes. Former athletes tend to adopt healthier lifestyles, which may give them an advantage in relation to risk factors taking into account metabolic risk factor/syndrome, diabetes mellitus and cardiovascular health. Health benefits of physical activities, moreover, depends of engagement at recommended levels, even in subjects who have never been athletes.

## Conflict of interests

There are no potential conflicts to declare.

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## References

- Aadahl, M., Kaer, M., & Jorgensen, T. (2007). Associations between overall physical activity level and cardiovascular risk factors in an adult population. *European Journal of Epidemiology*, 22(6), 369-378.
- Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., Meckes, N., Bassett Jr, D.R., Tudor-Locke, C., Greer, J.L., Vezina, J. Whitt-Glover, M.C., & Leon, A.S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine & Science in Sports & Exercise*, 43(8), 1575-1581.
- Alberti, K.G.M.M., Zimmet, P., & Shaw, J. (2006). Metabolic syndrome—a new world-wide definition. A consensus statement from the international diabetes federation. *Diabetic Medicine*, 23(5), 469-480.
- Backmand, H., Kaprio, J., Kujala, U. M., Sarna, S., & Fogelholm, M. (2006). Physical and psychological functioning of daily living in relation to physical activity. A longitudinal study among former elite male athletes and controls. *Aging Clinical and Experimental Research*, 18(1), 40-49.

- Backmand, H., Kujala, U., Sarna, S., & Kaprio, J. (2010). Former athletes' health-related lifestyle behaviours and self-rated health in late adulthood. *International Journal of Sports Medicine*, 31(10), 751-758.
- Batista, C., & Soares, J. M. (2013). Are former elite athletes more protected against metabolic syndrome? *Journal of Cardiology*, 61(6), 440-445.
- Batista, C.H., & Soares, J.M. (2014). Is athletic background associated with a future lower prevalence of risk factors for chronic disease? *Journal of Exercise Science & Fitness*, 12(2), 47-54.
- Boraita, A., Heras, M. E., Morales, F., Marina-Breyse, M., Canda, A., Rabadan, M., Barriopedro, M., Varela, A., de la Rosa, A., & Tunon, J. (2016). Reference Values of Aortic Root in Male and Female White Elite Athletes According to Sport. CLINICAL PERSPECTIVE. *Circulation: Cardiovascular Imaging*, 9(10), e005292.
- Braverman, A.C., Harris, K.M., Kovacs, R.J., & Maron, B.J. (2015). Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: task force 7: aortic diseases, including marfan syndrome: a scientific statement from the American Heart Association and American College of Cardiology. *Journal of the American College of Cardiology*, 66(21), 2398-2405.
- D'Andrea, A., Cocchia, R., Riegler, L., Salerno, G., Scarafile, R., Citro, R., Vriza, O., Limongelli, G., Di Salvo, G., Caso, P., Bossone, E., Calabrò, R., & Russo, M.G. (2012). Aortic stiffness and distensibility in top-level athletes. *Journal of the American Society of Echocardiography*, 25(5), 561-567.
- Expert Panel on Detection, E. (2001). Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *Jama*, 285(19), 2486-97.
- Ford, E.S., & Li, C. (2006). Physical activity or fitness and the metabolic syndrome. *Expert Review of Cardiovascular Therapy*, 4(6), 897-915.
- Gentry, J.L., Carruthers, D., Joshi, P.H., Maroules, C.D., Ayers, C.R., de Lemos, J.A., Aagard, P., Hachamovitch, R., Desai, M.I., Roselli, E.E., Dunn, R.E., Alexander, K., Lincoln, A.E., Tucker, A. M., & Phelan, D.M. (2017). Ascending Aortic Dimensions in Former National Football League Athletes. CLINICAL PERSPECTIVE. *Circulation: Cardiovascular Imaging*, 10(11), e006852.
- Grundey, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., Gordon, D.J., Krauss, R.M., Savage, P.J., Smith, S.C., Spertus, J.A., Costa, F., & Spertus, J.A. (2005). Diagnosis and management of the metabolic syndrome: An American Heart Association/National Heart, Lung, and Blood Institute scientific statement. *Circulation*, 112(17), 2735-2752.
- Haskell, W.L., Lee, I.M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D., & Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*, 116(9), 1081.
- Hiratzka, L.F., Bakris, G.L., Beckman, J.A., Bersin, R.M., Carr, V.F., Casey, D.E., Eagle, K.A., Hermann, L.K., Isselbacher E.M., Kazerooni, E.A., Kouchoukos, N.T., Lytle, B.W., Milewicz, D. M., Reich, D.L., Sen, S., Shinn, J. A., Svensson, L.G., & Williams, D.M. (2010). Guidelines for the diagnosis and management of patients with thoracic aortic disease: A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *Circulation*, 121(3), e266-e369.
- Hu, G., Qiao, Q., Silventoinen, K., Eriksson, J. G., Jousilahti, P., Lindström, J., Valle, T.T., Nissinen, A., & Tuomilehto, J. (2003). Occupational, commuting, and leisure-time physical activity in relation to risk for type 2 diabetes in middle-aged Finnish men and women. *Diabetologia*, 46(3), 322-329.
- Hu, G., Tuomilehto, J., Silventoinen, K., Barengo, N., & Jousilahti, P. (2004). Joint effects of physical activity, body mass index, waist circumference and waist-to-hip ratio with the risk of cardiovascular disease among middle-aged Finnish men and women. *European Heart Journal*, 25(24), 2212-2219.
- Iskandar, A., & Thompson, P.D. (2013). A meta-analysis of aortic root size in elite athletes. *Circulation*, 127, 791-798.
- Johansson, J.K., Kujala, U.M., Sarna, S., Karanko, H., Puukka, P.J., & Jula, A.M. (2016). Cardiovascular health in former elite male athletes. *Scandinavian Journal of Medicine & Science in Sports*, 26(5), 535-543.
- Kelly, D.F., Chaloner, C., Evans, D., Mathews, A., Cohan, P., Wang, C., Swerdloff, R., Sim, M.S., Lee, J., Wright, M.J., Kernan, C., Barkhoudarian, G., Yuen, K.C.J., & Guskiewicz, K. (2014). Prevalence of pituitary hormone dysfunction, metabolic syndrome, and impaired quality of life in retired professional football players: a prospective study. *Journal of Neurotrauma*, 31(13), 1161-1171.
- Kelley, D.E., & Goodpaster, B.H. (2001). Effects of exercise on glucose homeostasis in Type 2 diabetes mellitus. *Medicine and Science in Sports and Exercise*, 33(6 Suppl), S495-501.
- Kettunen, J.A., Kujala, U.M., Kaprio, J., Bäckmand, H., Peltonen, M., Eriksson, J.G., & Sarna, S. (2015). All-cause and disease-specific mortality among male, former elite athletes: an average 50-year follow-up. *British Journal of Sports Medicine*, 49(13), 893-897.
- Kinoshita, N., Mimura, J., Obayashi, C., Katsukawa, F., Onishi, S., & Yamazaki, H. (2000). Aortic root dilatation among young competitive athletes:

- echocardiographic screening of 1929 athletes between 15 and 34 years of age. *American Heart Journal*, 139(4), 723-728.
- Kohl, H.W. (2001). Physical activity and cardiovascular disease: evidence for a dose response. *Medicine and Science in Sports and Exercise*, 33(6), S472-S483.
- Kujala, U.M., Kaprio, J., Taimela, S., & Sarna, S. (1994). Prevalence of diabetes, hypertension, and ischemic heart disease in former elite athletes. *Metabolism*, 43(10), 1255-1260.
- Kumar Dey, S., Ghosh, C., Debray, P., & Chatterjee, M. (2002). Coronary artery disease risk factors & their association with physical activity in older athletes. *Journal of Cardiovascular Risk*, 9(6), 383-392.
- Laine, M.K., Eriksson, J.G., Kujala, U.M., Wasenius, N.S., Kaprio, J., Bäckmand, H.M., Peltonen, M., Mertsalmi, H., & Sarna, S. (2014). A former career as a male elite athlete—does it protect against type 2 diabetes in later life? *Diabetologia*, 57(2), 270-274.
- Laine, M.K., Eriksson, J.G., Kujala, U.M., Kaprio, J., Loo, B.M., Sundvall, J., Backmand, H.M., Peltonen, M., Jula, A., & Sarna, S. (2016). Former male elite athletes have better metabolic health in late life than their controls. *Scandinavian Journal of Medicine & Science in Sports*, 26(3), 284-290.
- Laine, M.K., Kujala, R., Eriksson, J.G., Kautiainen, H., Sarna, S., & Kujala, U.M. (2017). Costs of diabetes medication among male former elite athletes in later life. *Acta Diabetologica*, 54(4), 335-341.
- Laaksonen, D.E., Lakka, H.M., Salonen, J.T., Niskanen, L.K., Rauramaa, R., & Lakka, T.A. (2002). Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. *Diabetes Care*, 25(9), 1612-1618.
- Lee, I.M., & Paffenbarger Jr, R.S. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity: The Harvard Alumni Health Study. *American Journal of Epidemiology*, 151(3), 293-299.
- Maffulli, N., Longo, U.G., Gougoulias, N., Caine, D., & Denaro, V. (2010). Sport injuries: a review of outcomes. *British Medical Bulletin*, 97(1), 47-80.
- Morganroth, J., Maron, B.J., Henry, W.L., & Epstein, S.E. (1975). Comparative left ventricular dimensions in trained athletes. *Annals of Internal Medicine*, 82(4), 521-524.
- Paffenbarger Jr, R.S., Hyde, R.T., Wing, A.L., & Steinmetz, C.H. (1984). A natural history of athleticism and cardiovascular health. *Jama*, 252(4), 491-495.
- Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C., Buchner, M.P.H., Ettinger, W., Heath, G.W., King, A.C., Kriska, A., Leon, A.S., Marcus, B.H., Morris, J., Paffenbarger, R.S., Patrick, K., Pollock, M.L., James, M.R., Sallis, J., & Wilmore, J.H. (1995). Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Jama*, 273(5), 402-407.
- Pihl, E., Jurimae, T., & Kaasik, T. (1998). Coronary heart disease risk factors in middle-aged former top-level athletes. *Scandinavian Journal of Medicine & Science in Sports*, 8(4), 229-235.
- Pihl, E., Zilmer, K., Kullisaar, T., Kairane, C., Pulges, A., & Zilmer, M. (2003). High-sensitive C-reactive protein level and oxidative stress-related status in former athletes in relation to traditional cardiovascular risk factors. *Atherosclerosis*, 171(2), 321-326.
- Philipsen, A., Hansen, A.L., Jørgensen, M.E., Brage, S., Carstensen, B., Sandbaek, A., Almadal, T.P., Gram, J., pedersen, E.B., Lauritzen, T., & Witte, D.R. (2015). Associations of objectively measured physical activity and abdominal fat distribution. *Medicine and Science in Sports and Exercise*, 47(5), 983-989.
- Saltin, B., & Grimby, G. (1968). Physiological analysis of middle-aged and old former athletes: comparison with still active athletes of the same ages. *Circulation*, 38(6), 1104-1115.
- Sarna, S., Kaprio, J., Kujala, U. M., & Koskenvuo, M. (1997). Health status of former elite athletes. The Finnish experience. *Aging Clinical and Experimental Research*, 9(1-2), 35-41.
- Shaw, J.E., Sicree, R.A., & Zimmet, P.Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice*, 87(1), 4-14.
- Simon, J.E., & Docherty, C.L. (2014). Current health-related quality of life is lower in former Division I collegiate athletes than in non-collegiate athletes. *The American Journal of Sports Medicine*, 42(2), 423-429.
- Simon, J.E., & Docherty, C.L. (2017). The Impact of Previous Athletic Experience on Current Physical Fitness in Former Collegiate Athletes and Noncollegiate Athletes. *Sports Health*, 9(5), 462-468.
- Smith, D.J. (2003). A framework for understanding the training process leading to elite performance. *Sports Medicine*, 33(15), 1103-1126.
- Spirito, P., Pelliccia, A., Proschan, M.A., Granata, M., Spataro, A., Bellone, P., Caselli, G., Biffi, A., Vecchio, C., & Maron, B.J. (1994). Morphology of the "athlete's heart" assessed by echocardiography in 947 elite athletes representing 27 sports. *American Journal of Cardiology*, 74(8), 802-806.
- Surgeon General Surveillance Report*. (1999). Atlanta GA: National center for Chronic Disease Prevention and Health Promotion.
- Thune, I., Njolstad, I., Lochen, M.L., & Forde, O.H. (1998). Physical activity improves the metabolic risk profiles in men and women: The Tromso Study. *Archives of Internal Medicine*, 158(15), 1633-1640.
- Unt, E., Zilmer, K., Magi, A., Kullisaar, T., Kairane, C., & Zilmer, M. (2008). Homocysteine status in former top-level male athletes: possible effect of physical activity and physical fitness. *Scandinavian Journal of Medicine & Science in Sports*, 18(3), 360-366.
- U.S. Department of Health and Human Services 2008 Physical Activity Guidelines for Americans*. Washington, DC: U.S. Department of Health and Human Services.

- U.S. Department of Health and Human Services *Healthy People 2010*, vol. II. Washington, DC: U.S. Department of Health and Human Services.
- Utomi, V., Oxborough, D., Whyte, G. P., Somauroo, J., Sharma, S., Shave, R., Atkinson, G., & George, K. (2013). Systematic review and meta-analysis of training mode, imaging modality and body size influences on the morphology and function of the male athlete's heart. *Heart*, 99(23), 1727-1733.
- Vissers, D., Hens, W., Taeymans, J., Baeyens, J.P., Poortmans, J., & Van Gaal, L. (2013). The effect of exercise on visceral adipose tissue in overweight adults: a systematic review and meta-analysis. *PLoS one*, 8(2), e56415.
- Weiner, R.B., Wang, F., Isaacs, S.K., Malhotra, R., Berkstresser, B., Kim, J.H., Hutter, A.M., Picard, M.H., Wang, T.J., & Baggish, A.L. (2013). Blood Pressure and Left Ventricular Hypertrophy During American-Style Football Participation Clinical Perspective. *Circulation*, 128(5), 524-531.
- World Health Organization. (2002). *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*. World Health Organization.
- Wyshak, G. (2002). Behavior, heredity, and diabetes in college alumnae. *Journal of Women's Health & Gender-Based Medicine*, 11(6), 549-554.

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