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METABOLIC SYNDROME AND ITS COMPONENTS IN FORMER ATHLETES: A REVIEW

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ABSTRACT --*The benefits of physical activity on health are obvious in spite of the effects of participating in vigorous exercises and competitive sports in which they still remain uncertain. The present study examines the widespread presence of the syndrome and its components among former athletes, who were involved in various kind of sports. It also examines the relationship between long-term vigorous exercise training and metabolic syndrome rates and its components. The study examined 18 articles related to epidemiological studies and these articles were grouped based on the type of sport the article focused. The findings have shown that former athletes who participated in endurance training and who also participated in mixed sports have low prevalence of metabolic syndrome and its components when compared to the normal population. The findings also indicate that lower cardiovascular disease mortality is one of the main reasons for the lower metabolic syndrome percentages. On the contrary, for the former power athletes the results of researches are inconsistent. When former athletes engage in mixed sports the finding of researches show their metabolic rates are lower than the normal population. To conclude, long-term high intensity training is related to the decreasing rate of metabolic syndrome in specific groups of athletes.*

Keywords--*Metabolic syndrome. Former athletes. Cardiovascular disease. Type 2 Diabetes. Obesity/Overweight*.

I. INTRODUCTION

Recent research studies indicate that metabolic disease (MS) is increasingly recognised as a serious issue, as it increases the prevalence of obesity and diabetes(Aljabri, Bokhari, Alshareef, & Khan, 2018; Emami et al., 2018; Merja K. Laine et al., 2014). MS involves a combination of various cardiovascular risk factors, for instance, central obesity, high blood pressure, high blood sugar, and abnormal amount of lipids in the blood, either it is high or low (Aljabri et al., 2018; Batista & Soares, 2013; Emami et al., 2018; Panayiotoglou et al., 2017). These researches

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also have revealed that there is a strong relationship between cardiovascular risk factors and other chronic diseases problems such as type 2 diabetes (T2D) and cardiovascular disease (CVD). Data from several sources have reported that MS is the main risk factor for the morbidity and mortality of CVD and T2D. Meaning that, MS increases the risk of developing CVD by twofold and T2D by three to five fold, which can be a health risk issue (Aljabri et al., 2018; Kaur, 2014; O'Neill & O'Driscoll, 2015).

Engaging in physical activity (PA) and training in early stage of life has a significant role in later life (Batista & Soares, 2013, 2014; Merja K. Laine et al., 2014). Meaning that, It decreases the risk of high body fat, and contribute to sustain an ideal body weight. However, high accumulation of body fat could cause several diseases such as high blood pressure, high blood cholesterol, T2D, and coronary heart disease (Batista & Soares, 2013; Emami et al., 2018; Teramoto & Bungum, 2010). Even for elderly people, physical activity has a vital role in preventing several diseases, especially to avoid slow decline in functional capacities(Hardman & Stensel, 2009). It has been shown that engaging in regular PA has significant effect on improving cardiorespiratory fitness, muscular strength, body composition, lipid lipoprotein profiles, reduce blood pressure, inflammation, C-reactive protein, and lower the risk of death (Batista & Soares, 2013; Gremeaux et al., 2012; Hardman & Stensel, 2009; Mackie & Zafari, 2006; Melekoğlu, Sezgin, Işın, & Türk, 2019; Tran-Duy, Smerdon, & Clarke, 2018). American College of Sports Medicine and the American Heart Association have given certain guidelines for adults between the age 18 to 65 years (Haskell, Lee, Pate, Powell, & Blair, 2007), individuals are considered to have low level of PA even after retirement, if they participate in less than 150 minutes of moderate intensity PA.

Participating in physical sports in early life, as exemplified by professional athletes, can lower prevalence of several non-communicable disease such as T2D and high blood pressure and this will also help in maintaining psychological wellbeing in late adulthood (Bäckmand, Kaprio, Kujala, Sarna, & Fogelholm, 2006; Batista & Soares, 2013; M. K. Laine et al., 2017; Oliveira-Brochado, Oliveira-brochado, & Brito, 2010; Ströhle, 2009). According to Batista & Soares (2014), to be an athlete at a professional level is associated with a likelihood of decline for prevalence of several non-communicable disease. Batista & Soares (2013) have shown that former athletes may maintain appropriate level of physical fitness (PF) in comparing with general population, regardless of their participation in competitions or the level of PA.

Sports Science literature has emerged that the prevalence of MS, which has become a remarkable increase among athletes after retirement from competitive sport (Arliani et al., 2014; Emami et al., 2018; Guo, Zhang, Wang, Guo, & Xie, 2013). It has been reported that many of former athletes adopt a sedentary lifestyle after their retirement from games, and that can cause a threat of MS to their health (Arliani et al., 2014; Emami et al., 2018; Guo et al., 2013; Panayiotoglou et al., 2017; Pihl et al., 2003; Tucker et al., 2009). Functional capabilities in later life might be exposed because of the negative consequences of injuries during exercises and competitions. The high demands of athletes during adulthood probably make participants unable to stay active as they become older, and that could have an effect on their health (Melekoğlu et al., 2019). On the contrary, top athletes usually exercise for many years or even sometimes several decade to achieve their professional level, and when there is a lack of high-level training stimulus, they get affected physiologically and psychologically (Sunčica Poček et al., 2018). The following questions are formulated: (1) Do former athletes have lower prevalence of metabolic syndrome and its components than the general population, (2) Do participating in vigorous exercises have any significant influence after retiring from competition?

II. METHOD

The researchers looked for three English-language electronic databases; PubMed, Web of Science, and Google scholar (Alsolami, B., & Embi, M. R. , 2018). The keywords used were “metabolic syndrome”, “prevalence”, “former athletes”, “Cardiovascular risk factors”, and “Type 2 diabetes”. Several studies reported the prevalence of metabolic syndrome and its risk factors in former athletes. To assess the eligibility of articles. First, the researchers reviewed titles and abstracts of articles, and if there were no sufficient information in a particular title or abstract, they proceed to check the full text. After that, the quality of studies was assessed in relation to Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist for title, abstract, introduction, methods, results, and conclusion. Exclusion standard for including researches for this review was if they were published in different language other than English, a chapter in book, medical records, review papers. After the initial review of the related literatures only 18 suitable papers were chosen for a detailed review.

III. DEFINITION OF METABOLIC SYNDROME

According to Kaur (2014), the first concept of MS was made in 1920 by Kylin, who was a Swedish physician. After that, several definitions of the MS have been given in the literature, including the World Health Organization (WHO), the International Diabetes Federation (IDF), and the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) (2001), as they use different set of criteria. However, the definition of MS in relation to The National Cholesterol Education Program (NCEP/ATP III) and the World Health Organization (WHO) are the most used widely. On the other hand, ATP III criteria describe the MS according to the 3 of the following characteristics. Firstly, abdominal obesity, as a waist circumference >102 centimetres in male and >88 centimetres in female; triglycerides, ≥150 mg/dL or 1.7 mmol/L; HDL cholesterol, <40 mg/dL (1 mmol/L) in male and <50 mg/dL (1.3 mmol/L) in female; secondly, blood pressure (BP), ≥130/85 mm Hg; and thirdly, fasting plasma glucose, ≥110 mg/dL or 5.6 mmol/L” (Aljabri et al., 2018; Batista & Soares, 2013).

IV. RESULTS

The researchers identified five papers for former athletes in football , two papers for American football, one study for former athletes in strength and power, two papers for endurance and games sports, and three paper for endurance, mixed, and power sports, one paper for Endurance and power sports, and four papers for former athletes in all-sports. The key findings of these papers are illustrated in Table 1. The researches were conducted in Brazil, Estonia, Finland, Turkey, Greece, India, Iran, Portugal, and USA. Most of the papers focused on the male players, whereas five papers include both genders. Healthy lifestyles of former athletes give them a benefit regarding the risk factors that explain the syndrome in (Table 1). Furthermore, an adequate level of physical activity play a significant role in the association with metabolic syndrome and its risk factors, even people who never engage in any competitive sport (Batista, Cristiano & Soares, 2013). Based on the results of study, top former athletes who have been participating for long time in intensive training has low prevalence of type 2 diabetes compare to the control group. Laine (2014) showed that participants with the most leisure time physical activity in later life had

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the lowest prevalence of type 2 diabetes. High body mass index and fat accumulated in the abdominal area may be avoided by sustaining adequate levels of physical activities which plays an essential part (Aadahl, Kjær, & Jørgensen, 2007; Philipsen et al., 2015; Vissers et al., 2013).

Additionally, various researches have revealed that physical activity has a positive effect on glucose metabolism and blood pressure (Hu et al., 2004; Thune, Njølstad, Løchen, & Førde, 1999). Former elite athletes with a history of high intensity of physical activity have lower risk for metabolic syndrome, lower body fat percentage, and non-alcoholic fatty liver disease than the age-matched controls after retirement. Moreover, the current physical activity level has a significant effect. Individuals with high level of leisure time but do more physical activity normally have less body fat when they get older, less risk of metabolic syndrome, and non-alcoholic fatty liver disease. However, a long term effect of high intensity physical activity in adolescence and young adulthood is correlated with low prevalence of metabolic syndrome. The findings in earlier research has indicated that athletes who play at the top-levels have a lower incidence of diabetes(Sarna, Kaprio, Kujala, & Koskenvuo, 1997). The past research has shown that being a former athlete (Endurance, Sprinter, Jumper or team game athletes) reduced the burden of diabetes treatment in later life (Laine et al., 2017).

Researches conducted in football had shown that former athletes had a significantly lower incidence of type 2 diabetes, high blood pressure, metabolic syndrome, sitting time, and physical inactivity. Former footballer when they compared to the control group, they had 26% lower total-body fat percentage, 26% lower abdominal fat, and 13% higher muscle mass percentage, 37% higher in high-density lipoprotein cholesterol levels, HDL2-C levels were fourfold higher, and triglycerides were 31% lower in the former football players than the controls(Chang et al., 2009). On the contrary, prevalence of MS and its risk factors' percentages is observed among former endurance, football, and mixed-sports players. On the other hand, in regard to the power athletes, researchers have stated that former athletes had remarkably higher average amount of total body weight, body mass index when compared with active athletes and nonathletes (Emami et al., 2018). In addition, the findings indicated that former power athletes had higher diastolic blood pressure, low density lipoprotein cholesterol, insulin resistance when compared with active athletes and nonathletes. However, compared with nonathletes the average levels of high-density lipoprotein cholesterol were significantly lower in former power athletes. The research also reported that there was no significant difference among three groups in regard metabolic syndrome prevalence, even though its mean was lower between active athletes and nonathletes.

Authors	Country	Sport	Purpose	Participants	Gender	Measurements	Results
Arlini et al., 2014	Brazil	Football	Effects of football on health	Former athletes 100	Male	Health, economic, and social aspects	High body mass index, high use of tablets for knee pain.
Filho et al, 2015	Brazil	Football	To identify predictors of health-related quality of life among former athletes	Former athlete 186	Male & Female	The Short Form Health Survey (SF-36), Sociodemographic, health status, time since they stopped competing and leisure-time physical activity.	Sports injuries impact every-day activities, long term problems and body mass index were indictors of physical and mental health.
Pihl et al., 1998	Estonia	Endurance and games sports	To determine the effects of early athleticism in the risk factors of coronary heart disease	Former athlete 168 healthy men and 147 healthy pre-menopausal women	Male & Female	Anthropometric characteristics CHD risk factors, health habits, medical, safety, personal, psychological.	Significant differences in favour of former active athletes and people do leisure time physical activity. Diastolic blood pressure in males was significantly lower in active former athletes in females the systolic blood pressure was significantly higher in non-exercise people than other groups. For blood variables no significant differences reported between women's in all groups. In males, former active athletes had lower levels of tolerance glucose and low density lipoprotein cholesterol comparison with groups. Former active athletes and people with leisure time physical activity had a higher high density lipoprotein cholesterol levels.

Pihl et al., 2003	Estonia	Endurance and games sports	Analyze systemic and cellular oxidative stress-related indices as well as C-reactive protein level	Former athletes/ Sedentary controls 53/25	Male	Anthropometric factors , biochemical factors, leisure-time physical activity	Active former athletes had significantly lower values of fat percentage, body mass index, and waist to hip ratio, better spectrum of atherogenesis measurements than non-active former athletes. A significant association was reported between physical activity high blood pressure, high density lipoprotein cholesterol, density lipoprotein cholesterol, and glucose tolerance.
Johansson et al., 2016	Finland	Endurance and power sports	Effects of past and present-day physical activity on cardiovascular well-being	Former athlete/ Control 99/ 49	Male	physical and physiological measurements and heart structure and function	Former athletes engaging in high intensity physical activity in their leisure time had extra flexible arteries compared with whom participated in moderate physical activity in leisure time, high intensity leisure time activities during the whole lifetime associates with good health for cardiovascular.

Laine et al., 2014	Finland	Endurance, power, and mixed sports	Incidence of impaired glucose tolerance in top former Finnish athletes and compare them with controls with same area and age ?	Former athlete/ controls 392/207	Male	Glucose tolerance test by the mouth physiological information behaviour assessment smoking and physical activity	Former top athletes had a significantly decreased in the risk of type 2 diabetes compared with the control group. The risk of type 2 diabetes reduced when the amount of the leisure time physical activity is increased. They as well had a remarkably decreased in the risk of impaired glucose tolerance compared with the control group. Former top athletes might be prevent when they get old from type 2 diabetes and impaired glucose tolerance. The result indicated an inversely relationship between the amount of current the leisure time physical activity and the prevalence of type 2 diabetes.
Laine et al., 2016	Finland	Endurance, power, and mixed sports	Former top athletes have less body fat percentage, less risk of metabolic syndrome, and non-alcoholic fatty liver disease when they get old independent of the amount of present leisure time physical activity?	Former athlete/Controls 392/207	Male	Anthropometric data biochemical measurements	Former athletes had lower body fat percentage, non-alcoholic fatty liver disease, and metabolic syndrome risk factors compared with the control group. High amount of current physical activity in leisure time was inversely associated with lower body fat percentage, also a decreased in the risk of metabolic syndrome and non-alcoholic fatty liver disease risk with current physical activity in leisure time.

Laine et al., 2017	Finland	Endurance, power, and mixed sports	Whether high intensity exercise during youthhood is correlated with costs of diabetes therapy	Former athlete/Controls1314/860	Male	Diabetes medications data	Between mixed-sport athletes and former endurance athletes the total cost of diabetes therapy per individual yearly was notably lower, when compared with the control group. Former endurance athletes used insulin by 0.4%, whereas the control group used by 5.2%
Panayiotoglou et al,. 2017	Greece	Football	To investigate the prevalence of metabolic syndrome (MS) and its associates in retired professional soccer players compared to controls	Former athlete/ non athletes/ control 12/12	Male	Anthropometric and blood pressure measures and fasting blood samples Dietary intake health status and lifestyle	There is no difference between retired soccer players and control group. Former players with metabolic syndrome had obtained remarkable extra weight since they stopped playing, and they gained more total body fat, Fat Mass Index, and consume more calories. The results showed that players who obtained more than 12 kilogram after stop playing were at higher risk of having metabolic syndrome. However, players who obtained less

							than 12 kilograms were not risk of metabolic syndrome
Kumar Dey et al., 2002	India	Mixed sports	Effects of present-time physical activity on the risk factors for coronary artery disease in old athletes compared with matched age non-athletes	Active older athlete/ Sedentary older athlete/ Sedentary older non athlete 52/ 54 /56	Male	Body mass index physiological and biochemical measurement physical activity	Between the three groups there was a significant difference. The active older athletes and sedentary older non-athletes had significantly lower mean values in body weight, body fat percentage, body mass index, total cholesterol, triglycerides, and low-density lipoprotein, compared with the sedentary older athletes. An inverse trend seen in the situation of high-density lipoprotein. Furthermore, the currently active older athletes had significantly favourable levels of most of the risk factors for coronary artery disease compared to the sedentary older athletes and sedentary older non-athletes. A significant inverse relationship was reported for the current-day physical activity with triglycerides, levels of total cholesterol to high-density

							lipoprotein, low-density lipoprotein cholesterol, resting systolic blood pressure.
Emami et al, 2018	Iran	Power	assessing the risk of developing obesity, insulin resistance (IR), and metabolic syndrome among former power-sports athletes	athletes/Former athlete/ controls 34/30/30	Male	Demographic and anthropometric biochemical factors	Former athletes had remarkable high amount of total body weight, body mass index, insulin, low density cholesterol , and diastolic blood pressure when they compared with active athletes and normal people, whereas the mean level of high density cholesterol was significantly higher in normal people when compared with former athletes. The results reported no significant difference between the study groups in regards metabolic syndrome prevalence, even though its mean was high in former athletes.
Batista & Soares, 2013	Portugal	Mixed sports	Whether former athletes are better protected against MS, and if this can be different in regard gender, job, or later behaviours	Former athlete/ non athletes/ control 225/168/98	Male & Female	Demographic information Behavioural and biological characteristics Physical and biochemical measurements	There is no significant difference in the odds of MS among top former athletes, non-top athletes , and non-athletes. Moreover, no significant association of gender and past exercise intensity with the metabolic

							syndrome is reported. Even though, both non-top athletes and former top athletes who have been retired from sport and did not sustain the adequate levels of physical activity, showed a low likelihood of metabolic syndrome.
Batista & Soares, 2014	Portugal	Mixed sports	Investigate the difference between top former athletes (both gender) and non-top athletes and non-athletes in regard the prevalence of lifestyle and health risk factors	Former athlete/ non athletes/ control 225/168/98	Male & Female	Demographic information lifestyle and health features, body and blood assessment	In addition to drinking alcohol, former top athletes had 70% lower likelihood for the lifestyle hazard compared with non-athletes. Regarding physiological variables, small differences exists of having high body mass index, and only between female top athletes seemed to be higher compared with non-athletes.
Melekoglu et al., 2019	Turkey	Football	Effects of physical activity behaviours on former footballers	Former athletes 60	Male	Demographic information Behavioural and biological characteristics Physical and biochemical measurements	Active athletes had better body composition, blood lipids, and respiratory functions compared with non-active former footballers

Alice Y. Chang et al, 2009	USA	American football	Compared the risk factors of cardiovascular and coronary atherosclerosis in former national football league	Former athletes/ controls 150/150	Male	Demographic, health, and job information collected by questionnaire	Former players had significantly less incidences of diabetes, high blood pressure, sedentary behaviours, and metabolic syndrome, but had high incidences of impaired fasting glucose and blood lipid.
Brooks et al, 2013	USA	Mixed sport	To investigate the effects of early engagement in collegiate players	Former athlete 435	Male & Female	current health and activity status	There is a considerable increase from baseline in reporting of physical activity limitations were existing in male and female. The everyday physical activity limitations were 43% in males and 38% in females, physical activity limitations was 47% in females and 58% in males. Remarkable increase was reported in resting heart rate, blood pressure, body composition and total body weight for endurance and power athletes who before had been recorded as injuries.
Kelly et al., 2014	USA	Football	The relationship between brain injury and pituitary and metabolic syndrome in former footballer	National Football League / Control 68/30	Male	Demographic information lifestyle and health features, body and blood assessment	50% of former footballer had metabolic syndrome.

Marc et al, 2008	USA	American football	Assess the prevalence of metabolic syndrome and its individual component criteria	Former athlete 510	Male	self-reported demographic, medical, and professional career information	More metabolic syndrome was reported in linemen than non-linemen, high body mass index more than 30 kg/m2, lower high-density lipoprotein, and elevated fasting glucose were higher in linemen than non-linemen.

V. DISCUSSION

The purpose of this review is to investigate the prevalence of MS and its components in former athletes who played different sports, also to determine if long-term high physical sports is correlated with low MS. The research results of the epidemiological researches reported that long-term high intensity exercise could positively impact metabolic syndrome and its risk factors. Overall, former athletes in endurance and mixed-sports tend to have a lower prevalence of MS than the control groups (Laine 2014; Laine 2017). The low level of MS and risk factors between the above mentioned athletes seem to play a remarkable part in their well-being status. There are possible explanations of lowering MS and its components in former athletes. First, top athletes who involved in high amounts of high intensity exercise. It has suggested that a higher session of training has more benefits on lowering MS and its components. Second, higher PF levels which was achieved by top athletes may describe their lower prevalence of MS and its components. The results of this study has indicated that there is an inverse relationship between the levels of Physical Fitness and Metabolic Diseases and its components prevalence (Lemez & Baker, 2015; Teramoto & Bungum, 2010).

Result also suggest that cardiorespiratory fitness and PA are independently associated to coronary heart disease or CV risks factors. Top athletes are selected because they are in better health and high level of fitness who can play at high levels. The selected top athletes show that there is an impact of certain genetic factors. In the recent times the results shows a moderate to large genetic impact on PF components which is linked to human performance, for example maximal oxygen uptake and muscular endurance (Lemez & Baker, 2015; Teramoto & Bungum, 2010). Thus, people who become top players due to their genetic factors that are linked with great level of PF, which might offer them with lower prevalence of metabolic syndrome and its components.

Finally, retired athletes, especially endurance athletes usually choose to follow a healthy lifestyle and sustain their adequate levels of physical activity active when they get old, by participating in adequate levels of physical activity active and healthy behaviours compare to normal people (Laine et al., 2014). It has reported that athletes, regardless the type of sport, who participated in more PA levels at leisure time or competitive games and use less tobacco when compared to the control groups through their lifetime (Batista & Soares, 2014; Gomez-Gallego et al., 2010; Teramoto & Bungum, 2010).

It is interesting to see the variances of MS and its components between former athletes, who were playing in various sports. As stated earlier, athletes in endurance and mixed sports have lower prevalence of MS and its components than the general population. One of the possible reasons for this difference in MS is their endurance level and certain exercises might have contributed to the decrease in MS and its components. It is more evident in some cardiovascular diseases, which is influenced by training or resistance exercise(Gomez-Gallego et al., 2010). Cardiorespiratory fitness is enhanced by aerobic exercise, which is linked with lower the risk of several chronic diseases such as high blood pressure and type 2 diabetes, whereas the role of strength training is to prevent chronic diseases (Teramoto & Bungum, 2010). Another explanation for lower MS rates among former power athlete is also related to the high body fat and the increased risk of diabetes as they grow old (Chou et al., 2005). (Miller et al., 2008), reported that the prevalence of MS and its components such as high body mass index and elevated fasting glucose between top American football linemen was considerably greater than that between non-linemen counterparts (59.8% vs. 30.1%), whose activity involves a group of aerobic and anaerobic exercise. Results show that high body mass index, when comes together with diabetes, can significantly rise disease-specific mortality. On the top of that, the variances in MS prevalence between power athletes and other athletes in different type of sports may be because of the use of anabolic steroid which usually found between weightlifters and power athletes. It has been reported that the usage of steroid for long-period may cause adverse health effects like cardiovascular disease and liver dysfunction, in which they could cause early death (Teramoto & Bungum, 2010). It can be realized that researches in Table 1 did not find favourable MS. However, further research is needed to understand if strength training for athletes has any relationship with their MS and its components. This will help in taking decisions for steroid use.

VI. CONCLUSION

To conclude, top former endurance and mixed-sports athletes apparently to be healthier than the control groups due to their lower MS and its components. Therefore, long-term vigorous exercise training is associated with lower rates of MS and its components in these athletes. The possible factors for lower rates of MS and it components in former athletes are: the inverse correlation between PA and cardiometabolic disease , higher levels of PF reached by former athletes, the natural choice of those athletes, and the healthy behaviours and the adequate level of physical activity maintained by former athletes. Lower MS and its components of all-sports athletes suggest that elite athletes, lower rates than general populations. On the other hand, very few researches have focused on the beneficial of high intensity training on MS and its components in athletes of power sports. This could be because of the advantage of endurance training over strength exercise for decreasing cardiovascular disease and its risk factors, a higher occurrence of body mass index and diabetes in power athletes, and/or anabolic

steroid use being prevalent between power athletes. There is a growing need for research that examines the MS and their components among athletes from different kind of sports. Future researches also need to be conducted on female athletes to investigate whether sex has any impact on MS and its components of top athletes.

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