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Original Article

Association between cardiorespiratory, muscular fitness and metabolic syndrome in Korean men

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ABSTRACT

Aims: Cardiorespiratory and muscular fitness (CRF, MF) are independent predictor of metabolic syndrome (MS). The purpose of this study was to investigate the association between CRF, MF and MS in male adults.
Methods: Data collected from 10,774 males who visited the National Fitness Center between 2002 and 2009. The data included measurements of subjects' blood pressure, HDL-cholesterol, triglycerides, body mass index, CRF (VO_2max), MF (grip strength, push-up, sit-up, knee joint strength). CRF, MF level was classified into three tertiles.
Results: As for the prevalence rate according to CRF level, the differences between groups were 47.6% of the low CRF group, 33.1% of the middle CRF group, and 19.3% of the high CRF group were found to have MS. As for the MS prevalence rate according to MF level, the differences between groups were 47.1% of the low, 31.8% of the middle, 21.1% of the high MF group were found to MS. It was found that MS odds ratios (OR, 95% confidence interval) decreased as the CRF levels improved; as indicated by OR = 0.64 (0.57–0.72) in the middle CRF, OR = 0.36 (0.31–0.41) in the high CRF. As for MF, the middle MF, OR = 0.62 (0.55–0.70), the high MF, OR = 0.40 (0.35–0.45) were lower than that of the low MF.
Conclusion: The level of CRF, MF has association with MS in men. This study suggests that we need to manage our fitness to prevent MS.

1. Introduction

Metabolic syndrome is a key risk factor of cardiovascular diseases (CVD), As the importance of early detection is widely recognized [1,2]. Untreated metabolic syndrome elevates the risk of developing type 2 diabetes, hypertension, high cholesterol, and other cardiovascular diseases, all of which negatively affects the quality of life owing deteriorating health and an increased mortality rate [3]. Not one particular factor is associated with metabolic syndrome. In fact, interaction between various factors have been shown to cause the condition, such, a multi-faceted research is needed for effective prevention and treatment.

Metabolic syndrome is a chronic disease that is known to be closely associated with an individual's lifestyle [4,5]. Engaging in regular physical activity, quitting smoking and maintaining a healthy, and diet are recommended as part of a healthy lifestyle to reduce the risk of metabolic diseases [6]. Numerous metabolic studies have pointed out obesity, high blood pressure, high cholesterol, and impaired fasting glucose as risk factors of CVD, and they have reported that lifestyle changes are critical in reducing the risk of developing condition [7,8]. Along with lifestyle change, improving health-related fitness is also critical. In particular cardiorespiratory fitness is associated with major diseases such as CVD and cancers and it has been identified as a key predictor of premature death [9,10]. Cardiorespiratory fitness is independently associated with a lowered risk of CVD, and the risk of chronic diseases increases with a significant decrease in cardiorespiratory fitness [11–13].

Recently muscular fitness has been found to be factor influencing the risk of chronic diseases and associated premature deaths [14–16]. Hoekstra et al. [17], suggested a link between muscular fitness and CVD. Studies by Jurca et al. [18], and Wijndaele et al.

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[19], reported a negative correlation between metabolic syndrome and muscular fitness. Yang et al. [20], found that the risk of metabolic diseases is higher among the elderly who tends to have low level of muscular fitness, and Steene-Johanneen et al. [21], also reported on the negative correlation between muscular fitness and metabolic syndrome.

Clearly, the correlation between chronic diseases and cardiorespiratory diseases can be confirmed in many existing studies. However, not enough studies are available, in which the association between muscular fitness and metabolic syndrome are examined.

In light of these issues, the current study aims to verify the association between cardiorespiratory fitness, muscular fitness, and metabolic syndrome by examining large-scale data on male adult population in Korea. In addition, the present study analyzes the risk of metabolic syndrome according to fitness level and provides basic data for prevention of metabolic syndrome in the future.

2. Methods

2.1. Study population

Potential subjects of the current study included 13,790 male adults 20–69 years, who visited the National Fitness Center for health checkups between January 2002 and December 2009. Upon excluding those with inadequate data and those who had a history of cerebrovascualr disease, CVD, orthopedic conditions, or cancers, a total of 10,774 subjects were selected for the cross-sectional study examining the association between fitness level and metabolic syndrome. Data analysis in this study began upon obtaining the approval of the Catholic university's clinical research review board (CUMC11U011).

2.2. Metabolic syndrome risk factors measurements

For blood pressure, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice with an oscillometric automatic blood pressure monitor (FT-500R plus, Jawon, Korea) after a 10-min relaxation period. The average value was recorded. For blood analysis, a sample was taken from the brachial vein after a 12-h fasting period. Analysis of total cholesterol, HDL (high-density lipoprotein cholesterol), LDL (low-density lipoprotein cholesterol), triglycerides, and fasting glucose was performed with the use of a biochemical analyzer (Selecta XL, Vital scientific, Newton, MA).

2.3. Cardiorespiratory fitness and muscular fitness measurements

For measurement of cardiorespiratory fitness, a treadmill graded exercise test (GXT) was administered while using an automatic breathalyzer system (Q4500, Quinton, Bothell, UAS) and a modified Balke protocol. For measurement of muscular endurance, a push-up test and a sit-up test were administered. A push-up counter (NTCS 1001, Nuritec, Korea) was used to measure the number of push-ups performed to the point of failure, with no time limit set. A sit-up counter (NTES 1001, Nuritec, Korea) was used to measure the number of sit-ups performed during a 1-min period. Muscle grip strength was measured with a Smedley grip strength tester (NTCS 1001, Nuritec, Korea), and knee extensor strength was measured with a isokinetics strength tester (Biodex 3.0, Biodex, Shirley, NY, USA).

2.4. Metabolic syndrome diagnostic criteria

Metabolic syndrome diagnostic criteria consisted of the 5 components suggested by the National Cholesterol Education Program Treatment Panel III [22], with the exception of waist measurement which was substituted with BMI. The BMI classification for Asian populations suggested by the WHO [23], was consulted. Subjects were diagnosed with metabolic syndrome if three or more of the following conditions were met: HDL 40 mg/dL $\leq$, triglycerides 150 mg/dL $\geq$, SBP and DBP at rest 130 $\geq$ or 85 mmHg $\geq$, fasting glucose 100 mg/dL $\geq$, BMI 25 kg/m^2 $\geq$.

2.5. Cardiorespiratory fitness and muscular fitness standards

Because physical fitness varies by age, subjects were divided into age groups (20s, 30s, 40s, 50s, 60s) for the analysis. Cardiorespiratory fitness (CRF) was divided into 3 levels (tertile: 33.3%, 66.6%). Subjects in the lowest tertile ($\leq$33.3%) had "low CRF", those in the second tertile (>33.3%, $\leq$66.6%) had "middle CRF", and those in the highest tertile (>66.6%) had "high CRF".

For muscular fitness (MF), subjects' standardized scores [standardized z-score = value-mean/standard deviation] pertaining to push-ups, sit-ups, grip strength, and knee extensor strength were combined and then divided into tertiles. Subjects in the lowest tertile ($\leq$33.3%) were determined to have "low MF", those in the second tertile (>33.3%, $\leq$66.6%) were determined to have "middle MF", and those in the highest tertile (>66.6%) were determined to have "high MF".

2.6. Statistical analysis

In order to examine general characteristics of the subjects, the average values and standard deviations were obtained for the continuous variables including body measurement, fitness measurement, and metabolic syndrome factors. Categorical variables, such as history of exercising, and drinking, and smoking, were measured in frequencies and percentages.

Prevalence of metabolic syndrome and prevalence of individual abnormal risk factors according to the 3 levels of cardiorespiratory fitness and muscular fitness were calculated while using the chi-square test. Additionally, in order to examine the differences between the metabolic syndrome risk factors according to fitness level, an ANCOVA was performed with history of exercising, smoking, and drinking as covariates. In order to examine the simple correlation between metabolic syndrome and muscular and cardiorespiratory fitness, a logistic regression analysis was performed and odds ratios were calculated. All statistical analysis was performed using SAS (version 9.1), and the significance level was set at $p < 0.05$.

3. Results

3.1. General characteristics of subjects

The 10,774 subjects consisted of 8989 healthy subjects and 1785 patients with metabolic syndrome patients. The average age was 46.5 aged. Some of the metabolic syndrome risk factors, such as SBP, DBP, triglycerides, blood glucose, and BMI measured significantly higher in the metabolic syndrome group than the healthy group. In contrast, HDL measured lower in the metabolic syndrome group. VO_2max measured at 41.1 mL/kg/min in the healthy group, which was significantly higher than 37.4 mL/kg/min of metabolic syndrome group. Standardized score for muscular fitness measured at 0.24 in the healthy group, which was significantly higher than the metabolic −1.22 of metabolic syndrome group (Table 1).

3.2. Prevalence of metabolic syndrome according to cardiorespiratory and muscular fitness levels

In order to examine the prevalence of metabolic syndrome

Table 1
General characteristics of participants.

	No MS (N = 8989)	MS (N = 1785)	Total (N = 10,774)	*p* valve
Age (years)	46.0 ± 9.7	49.1 ± 8.9	46.5 ± 9.6	<0.001
20-29	385 (92.8)	30 (7.2)	415 (3.9)	–
30-39	2025 (89.4)	241 (10.6)	2266 (21.0)	–
40-49	3250 (83.6)	636 (16.4)	3886 (36.1)	–
50-59	2470 (80.1)	614 (19.9)	3084 (28.6)	–
60-69	859 (76.5)	264 (23.5)	1123 (10.4)	–
Weight (kg)	69.6 ± 8.9	77.6 ± 8.8	70.9 ± 9.3	<0.001
Height (cm)	170.4 ± 5.7	169.7 ± 5.9	170.3 ± 5.7	<0.001
Exercise status (%)	5257 (58.5)	1000 (56.0)	6257 (58.1)	0.036
Smoking status (%)	3169 (35.3)	669 (37.5)	3838 (35.6)	0.021
Drinking status (%)	7062 (78.6)	1442 (80.8)	8503 (78.9)	0.023
Metabolic syndrome risk factors				
SBP (mmHg)	121.5 ± 13.9	136.4 ± 13.1	123.9 ± 14.8	<0.001
DBP (mmHg)	75.4 ± 10.6	85.4 ± 10.1	77.0 ± 11.1	<0.001
HDL (mg/dL)	52.4 ± 11.2	46.2 ± 11.7	51.4 ± 11.5	<0.001
TG (mg/dL)	116.9 ± 56.9	195.3 ± 64.7	129.8 ± 65.1	<0.001
FG (mg/dL)	86.1 ± 11.0	98.4 ± 17.3	88.1 ± 13.1	<0.001
BMI (kg/m^2)	23.9 ± 2.6	26.9 ± 2.5	24.4 ± 2.8	<0.001
Fitness factor				
Cardiorespiratory fitness				
VO_2max (mL/kg/min)	41.1 ± 7.3	37.4 ± 6.6	40.4 ± 7.3	<0.001
Muscular fitness				
Sum of z-score	0.24 ± 2.84	−1.22 ± 2.54	0.0 0 ± 2.8	<0.001
Push–up (count)	21.4 ± 10.4	18.2 ± 9.4	20.8 ± 10.2	<0.001
Sit-up (count per min)	28.6 ± 9.4	26.9 ± 8.9	28.3 ± 9.3	<0.001
Grip strength/weight (%)	65.5 ± 10.7	59.7 ± 9.0	64.5 ± 10.6	<0.001
Knee extensor (% BW)	239.5 ± 41.9	221.0 ± 40.1	236.4 ± 42.1	<0.001

Data shown as Mean ± SD or N (%).
MS; metabolic syndrome, Exercise status; ≥30 min/day on ≥3 day/week, Smoking status; ≥1 cigarettes daily, Drinking status; ≥ once/month.
SBP; systolic blood pressure, DBP; diastolic blood pressure, HDL; high density lipoprotein cholesterol, TG; triglycerides, FG; fasting glucose, BMI; body mass index.
z-score=(value-mean)/(standard deviation).
Tested by *t*-test or chi-square test.

according to cardiorespiratory and muscular fitness, these fitness type were each divided into 3 levels, and the prevalence of abnormal risk factors was measured for each fitness level. Table 2 displays the analysis results. As for the prevalence rate according to cardiorespiratory fitness level, the differences between groups were significant, 47.6% of the low CRF group, 33.1% of the middle CRF group, and 19.3% of the high CRF group were found to have metabolic syndrome, these group differences were significant.

As for blood pressure, 38.2% of the low group, 32.4% of the middle group, and 29.4% of the high CRF group were found to have high blood pressure, indicating that blood pressure decreased as fitness level increased. Similar patterns were observed in terms of HDL. Triglycerides, blood glucose, and BMI all, tended to decrease as the fitness level increase.

As for the prevalence rate according to muscular fitness level, the differences between groups were significant, 47.1% of the low, 31.8% of the middle, and 21.1% of the high MF group were found to have metabolic syndrome. Similar patterns were observed in terms of blood pressure, triglycerides, blood glucose, and BMI, indicating that prevalence rate dropped as muscular fitness increased. As for HDL, 33.9% of the low 33.7% of the middle, and 32.3% of the high MF group had low HDL, but these intergroup differences were not significant.

3.3. Differences in metabolic syndrome risk factors according to cardiorespiratory and muscular fitness

In order to examine the differences in the metabolic syndrome risk factors according to cardiorespiratory and muscular fitness levels, a comparison was performed with age, exercise status,

Table 2
Prevalence of metabolic syndrome according to cardiorespiratory and muscular fitness levels.

	Metabolic syndrome	BP	HDL	TG	FG	BMI
		≥130 or 85 mmHg	≤40 mg/dL	≥150 mg/dL	≥100 mg/dL	≥25 kg/m^2
Cardiorespiratory fitness						
Low	47.6 (849)	38.2 (1399)	38.7 (580)	43.9 (1471)	40.1 (590)	43.7 (1922)
Middle	33.1 (591)	32.4 (1187)	32.0 (480)	34.2 (1145)	32.4 (476)	34.1 (1503)
High	19.3 (345)	29.4 (1077)	29.3 (440)	21.9 (735)	27.5 (405))	22.2 (977)
p valve	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Muscular fitness						
Low	47.1 (841)	37.6 (1379)	33.9 (509)	42.1 (1412)	39.8 (585)	46.0 (2023)
Middle	31.8 (568)	32.4 (1185)	33.7 (506)	32.8 (1100)	33.2 (489)	33.1 (1456)
High	21.1 (376)	30.0 (1099)	32.3 (485)	25.0 (839)	27.0 (397)	21.0 (923)
p valve	<0.001	<0.001	0.427	<0.001	<0.001	<0.001

Data shown as % (N).
BP; Blood pressure, HDL; High density lipoprotein cholesterol, TG; Triglycerides, FG; Fasting glucose, BMI; Body mass index.
Tested by chi-square test adjusted for age, exercise, smoking and drinking.

smoking status, and drinking status as covariates. Table 3 shows the results of the comparison. When all groups' risk factors according to cardiorespiratory fitness were examined, the low CRF group exhibited SBP = 125.9 mmHg, the middle group, SBP = 123.7 mmHg, and the high group SBP = 122.2 mmHg, indicating a significant decrease with increasing fitness level. Similar patterns were observed in terms of DBP, triglycerides, blood pressure, and BMI, which decreased significantly as cardiorespiratory fitness increased. However, no significant changes were found in terms of HDL.

As for muscular fitness, the low MF group exhibited SBP = 125.7 mmHg, the middle group, SBP = 123.8 mmHg, and the high group, SBP = 122.5 mmHg, indicating that DBP decreased significantly as muscular fitness increased. Similar patterns were observed in terms of blood pressure, triglycerides, blood glucose, and BMI, which decreased significantly as muscular fitness increased. However, no significant change were observed in terms of HDL.

The metabolic syndrome risk factors were compared between the healthy group and the metabolic syndrome group. In the healthy group, the differences in risk factors according to cardiorespiratory and muscular fitness, showed a similar pattern to the previous comparison involving the entire group of subjects. In the metabolic syndrome group, only SBP, triglycerides, and BMI were found to vary according to cardiorespiratory fitness level. As for muscular fitness, only HDL and BMI varied according to muscular fitness.

Table 4
Odds ratio of having the metabolic syndrome according to level of cardiorespiratory fitness and muscular fitness.

	OR	95% CI
Cardiorespiratory fitness		
Low	1.00	
Middle	0.64	0.57–0.72
High	0.36	0.31–0.41
Muscular fitness		
Low	1.00	
Middle	0.62	0.55–0.70
High	0.40	0.35–0.45

OR: odds ratio.
Tested by logistic regression analysis adjusted for age, exercise, smoking and drinking.

3.4. Odds ratio of having the metabolic syndrome according to level of cardiorespiratory fitness and muscular fitness

In order to examine the effects of cardiorespiratory and muscular fitness on metabolic syndrome, odds ratio were calculated based on age, exercise status, smoking status, and drinking status as covariates. Table 4 displays the results. As cardiorespiratory fitness increased, OR decreased significantly, OR = 0.64 (95% CI 0.57–0.72) in the middle CRF and, OR = 0.36 (95% CI 0.3 1–0.41) in the high CRF group. As for muscular fitness, the results were: OR = 0.62 (95% CI 0.55–0.70) in the middle CRF, and OR = 0.40 (95% CI 0.35–0.45) in the high CRF group, which showed a significant decrease.

Table 3
Differences in metabolic syndrome risk factors according to cardiorespiratory and muscular fitness.

	SBP (mmHg)	DBP (mmHg)	HDL (mg/dL)	TG (mg/dL)	FG (mg/dL)	BMI (kg/m^2)
Total						
Cardiorespiratory fitness						
Low	125.9 ± 15.2	78.5 ± 11.3	50.7 ± 11.5	146.3 ± 68.1	89.2 ± 14.0	25.3 ± 3.0
Middle	123.7 ± 14.7	76.9 ± 11.1	51.4 ± 11.4	131.6 ± 64.8	88.1 ± 12.9	24.4 ± 2.6
High	122.2 ± 14.2	75.6 ± 10.8	52.1 ± 11.7	111.2 ± 57.0	86.9 ± 12.1	23.5 ± 2.4
p valve	<0.001	<0.001	0.100	<0.001	<0.001	<0.001
Muscular fitness						
Low	125.7 ± 15.1	78.2 ± 11.3	51.3 ± 11.5	143.5 ± 67.9	89.4 ± 14.1	25.6 ± 3.0
Middle	123.8 ± 15.0	77.0 ± 11.3	51.3 ± 11.5	129.6 ± 64.3	88.0 ± 13.1	24.3 ± 2.6
High	122.5 ± 14.2	75.9 ± 10.8	51.6 ± 11.7	116.5 ± 60.2	87.0 ± 12.0	23.4 ± 2.5
p valve	<0.001	<0.001	0.827	<0.001	<0.001	<0.001
Non metabolic syndrome						
Cardiorespiratory fitness						
Low	122.5 ± 14.1	76.3 ± 10.6	52.0 ± 11.0	129.6 ± 59.4	86.5 ± 11.5	24.7 ± 2.9
Middle	121.4 ± 13.8	75.3 ± 10.6	52.5 ± 11.1	119.4 ± 57.8	86.2 ± 10.9	24.0 ± 2.5
High	120.8 ± 13.6	74.6 ± 10.5	52.8 ± 11.6	103.5 ± 50.6	85.7 ± 10.7	23.3 ± 2.3
p valve	<0.001	<0.001	0.887	<0.001	0.002	<0.001
Muscular fitness						
Low	122.3 ± 14.0	76.0 ± 10.5	52.6 ± 11.0	127.0 ± 59.8	86.5 ± 10.9	25.0 ± 2.8
Middle	121.4 ± 13.9	75.4 ± 10.7	52.4 ± 11.2	117.8 ± 57.3	86.2 ± 11.6	23.9 ± 2.5
High	120.9 ± 13.7	74.8 ± 10.4	52.3 ± 11.5	107.4 ± 52.2	85.8 ± 10.5	23.1 ± 2.3
p valve	<0.001	<0.001	0.027	<0.001	0.029	<0.001
Metabolic syndrome						
Cardiorespiratory fitness						
Low	137.0 ± 13.4	85.7 ± 10.5	46.3 ± 12.2	200.8 ± 66.4	98.5 ± 17.4	27.4 ± 2.8
Middle	135.7 ± 13.1	85.0 ± 10.1	46.1 ± 11.4	194.1 ± 62.8	98.3 ± 17.2	26.6 ± 2.0
High	136.4 ± 12.6	85.4 ± 9.3	45.9 ± 11.1	183.8 ± 62.2	98.4 ± 17.3	26.3 ± 2.1
p valve	0.029	0.114	0.169	0.007	0.562	<0.001
Muscular fitness						
Low	136.7 ± 13.3	85.6 ± 10.3	46.8 ± 11.9	197.8 ± 64.5	99.1 ± 18.2	27.6 ± 2.7
Middle	136.5 ± 13.9	85.4 ± 10.4	45.4 ± 11.5	192.2 ± 63.1	97.7 ± 15.9	26.5 ± 2.1
High	135.8 ± 11.5	85.0 ± 9.3	46.0 ± 11.8	194.4 ± 67.3	97.8 ± 17.3	26.0 ± 2.1
p valve	0.174	0.207	0.016	0.426	0.079	<0.001

Data shown as Mean ± SD.
SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL: high density lipoprotein cholesterol, TG: triglycerides, FG: fasting glucose, BMI: body mass index.
Tested by ANCOVA adjusted for age, exercise, smoking and drinking.

4. Discussion

The present study aimed to investigate the association between cardiorespiratory, muscular fitness and metabolic syndrome in male adults. In this study VO_2max was used as a cardiovascular fitness index, and muscle fitness was measured using the standardized scores of push-up, sit-up, grip strength, knee extension strength.

In current study the higher the cardiorespiratory fitness level, the lower the prevalence of metabolic syndrome, and that the relative risk of developing metabolic syndrome was lower as cardiovascular fitness increased. Additionally, it showed that a high level of cardiorespiratory fitness is associated with decreasing metabolic syndrome factors. Jurca et al. [18], study involving 8570 male adults, as well as Boulé et al. [24], study involving 348 males and females support the results of the current study. Low levels are cardiorespiratory fitness is associated with a high prevalence rate of CVD and associated death rate [25,26]. Maintaining a high level of cardiorespiratory fitness can prevent various chronic diseases and reduce the risk of death by CVD [10,27]. A similar prospective study by LaMonte et al. [28], reported that according to how greater the decrease in cardiorespiratory fitness was the risk of metabolic syndrome increases by 1.45–1.64 times.

Also muscular fitness studies found that higher muscular fitness is associated with lower risk of metabolic syndrome. In addition, we found that the relative risk of developing metabolic syndrome was lower as muscular fitness increased. Wijndaele et al. [19], study on adults also found that metabolic syndrome decreased as muscular fitness increased, which is similar to the current study's findings. Yang et al. [20], study on the elderly, and Steene-Johannessen et al. [21], study on teenagers, also reported a similar results, indicating a negative correlation between metabolic syndrome and muscular fitness. Although that were not metabolic syndrome studies, several prospective studies on chronic diseases, such as Silventoinen et al. [29], study reported that knee extensor strength is closely tied to CAD, and increased muscular strength can decrease the risk of CVD by 8–10%. According to Shrier et al. [30], decreased grip strength and knee extensor strength can affect high blood pressure. Ling et al. [31], reported that a significant decrease in elderly people's grip strength can increase the risk of CVD by about 1.8–2 times. As seen in existing studies, the location of measurement of muscular strength in the body and whether the muscle can be isolated, may affect the results. However a decrease in muscular fitness, as seen in this study, can have an effect on metabolic syndrome. The typical goal of health-related fitness training is disease prevention by balancing cardiorespiratory and muscular fitness. The current study shows that cardiorespiratory and muscular fitness are a predictor of metabolic syndrome risk. Therefore, maintaining good levels of the fitness was thought to be important for prevention of metabolic syndrome.

One of the limitations of this study is was that its subjects tended to be health-conscious individuals with a high rate of health checkups, which leaves room for selection bias. Additionally, other factors such as medication use, socio-economic factors, and lifestyle were not sufficiently accounted for. Nevertheless, the study is a large-scale study that used the data collected from over 10,000 individuals. It is meaningful in that it incorporated a graded exercise stress test and a fitness test in order to evaluate cardiorespiratory and muscular fitness.

5. Conclusion

This study indicated that in adult males cardiorespiratory and muscular fitness is associated with metabolic syndrome. Efforts to maintain a certain level of fitness must be made for to prevent of metabolic syndrome. Additionally, programs that foster both cardiorespiratory and muscular fitness need to be developed. A comprehensive prospective study involving a large cohort is needed to examine the effects of changes in fitness on metabolic syndrome and other chronic diseases.

Conflicts of interest

The authors have no conflicts of interest relevant to this study.

References

[1] Gami AS, Witt BJ, Howard DE, Erwin PJ, Gami LA, Somers VK, et al. Metabolic syndrome and risk of incident cardiovascular events and death: a systematic review and meta-analysis of longitudinal studies. J Am Coll Cardiol 2007;49:403–14.
[2] Schmidt C, Bergström GM. The metabolic syndrome predicts cardiovascular events: results of a 13-year follow-up in initially healthy 58-year-old men. Metab Syndrome Relat Disord 2012;10:394–9.
[3] Isomaa B, Almgren P, Tuomi T, Forsén B, Lahti K, Nissén M, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. Diabetes Care 2001;24:683–9.
[4] Bo S, Ciccone G, Baldi C, Benini L, Dusio F, Forastiere G, et al. Effectiveness of a lifestyle intervention on metabolic syndrome. A randomized controlled trial. J Gen Intern Med 2007;22:1695–703.
[5] Gerstel E, Pataky Z, Busnel C, Rutschmann O, Guessous I, Zumwald C, et al. Impact of lifestyle intervention on body weight and the metabolic syndrome in home-care providers. Diabetes Metab 2013;39:78–84.
[6] Maki KC. Dietary factors in the prevention of diabetes mellitus and coronary artery disease associated with the metabolic syndrome. Am J Cardiol 2004;93:12–7.
[7] Giugliano D, Ceriello A, Esposito K. The effects of diet on inflammation: emphasis on the metabolic syndrome. J Am Coll Cardiol 2006;48:677–85.
[8] Lee KS, Cho SD, Hong HS. The risk factors associated with increased blood pressure, sugar and lipids in multi-phasic health checkup examinee. Korean J Prev Med 2000;33:69–75.
[9] O'Hartaigh B, Jiang CQ, Thomas GN, Tsvetanov KA, Bosch JA, Cheng KK, et al. Usefulness of physical fitness and the metabolic syndrome to predict vascular disease risk in older Chinese from the Guangzhou Biobank Cohort Study-Cardiovascular Disease Subcohort [GBCS-CVD]. Am J Cardiol 2011;108:845–50.
[10] Kokkinos P, Myers J, Faselis C, Panagiotakos DB, Doumas M, Pittaras A, et al. Exercise capacity and mortality in older men, A 20-year follow-up study. Circulation 2010;24:790–7.
[11] Mileski KS, Leitão JL, Lofrano-Porto A, Grossi Porto LG. Health-related physical fitness in middle-aged men with and without metabolic syndrome. J Sports Med Phys Fit 2015;55:223–30.
[12] Lewis JE, Cutrono S, Hodgson N, LeBlanc WG, Arheart KL, Fleming LE, et al. Association between cardiovascular fitness and metabolic syndrome among American workers. J Occup Environ Med 2015;57:129–33.
[13] Shuval K, Finley CE, Barlow C, Gabriel KP, Leonard D, Kohl HW. Sedentary behavior, cardiorespiratory fitness, physical activity, and cardiometabolic risk in men: the cooper center longitudinal study. Mayo Clin Proc 2014;89:1052–62.
[14] Artero EG, Lee DC, Lavie CJ, España-Romero V, Sui X, Church TS, et al. Effects of muscular strength on cardiovascular risk factors and prognosis. J Cardiopulm Rehabil Prev 2012;32:351–8.
[15] Roberts CK, Lee MM, Katiraie M, Krell SL, Angadi SS, Chronley MK, et al. Strength fitness and body weight status on markers of cardiometabolic health. Med Sci Sports Exerc 2015;47:1211–8.
[16] Ruiz JR, Sui X, Lobelo F, Morrow Jr JR, Sjostrom M, Blair SN. Association between muscular strength and mortality in men: prospective cohort study. BMJ 2008;337:92–5.
[17] Hoekstra T, Boreham CA, Murray LJ, Twisk JW. Associations between aerobic and muscular fitness and cardiovascular disease risk: the Northern Ireland young hearts study. J Phys Activ Health 2008;5:815–29.
[18] Jurca R, Lamonte MJ, Church TS, Earnest CP, Fitzgerald SJ, Barlow CE, et al. Associations of muscle strength and fitness with metabolic syndrome in men. Med Sci Sports Exerc 2004;36:1301–7.
[19] Wijndaele K, Duvigneaud N, Matton L, Duquet W, Thomis M, Beunen G, et al. Muscular strength, aerobic fitness, and metabolic syndrome risk in Flemish adults. Med Sci Sports Exerc 2007;39:233–40.
[20] Yang EJ, Lim S, Lim JY, Kim KW, Jang HC, Paik NJ. Association between muscle strength and metabolic syndrome in older Korean men and women: the Korean Longitudinal Study on Health and Aging. Metabolism 2012;61:317–24.
[21] Steene-Johannessen J, Anderssen SA, Kolle E, Andersen LB. Low muscle fitness is associated with metabolic risk in youth. Med Sci Sports Exerc 2009;41:1361–7.
[22] Grundy SM, Brewer HB, Jr Cleeman JI, Smith Jr SC, Lenfant C. National heart, lung, and blood institute; American Heart Association. Definition of metabolic

syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. Arterioscler Thromb Vasc Biol 2004;24:13–8.
[23] World Health Organization Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–63.
[24] Boulé NG, Bouchard C, Tremblay A. Physical fitness and the metabolic syndrome in adults from the Quebec Family Study. Can J Appl Physiol 2005;30:140–56.
[25] Gupta S, Rohatgi A, Ayers CR, Willis BL, Haskell WL, Khera A. Cardiorespiratory fitness and classification of risk of cardiovascular disease mortality. Circulation 2011;123:1377–83.
[26] Stephen WFL, Carrie EF, Scott MG. Cardiorespiratory fitness, LDL cholesterol, and CHD mortality in men. Med Sci Sports Exerc 2012;44:2132–7.
[27] Lee DC, Artero EG, Sui X, Blair SN. Mortality trends in the general population: the importance of cardiorespiratory fitness. J Psychopharmacol 2010;24:27–35.
[28] LaMonte MJ, Bariow CF, Jurca R, Kampert JB, Church TS, Blair SN. Cardiorespiratory fitness in inversely associated with the incidence of metabolic syndrome: a prospective study of men and women. Circulation 2005;112:505–12.
[29] Silventoinen K, Magnusson PK, Tynelius P, Batty GD, Rasmussen F. Association of body size and muscle strength with incidence of coronary heart disease and cerebrovascular diseases: a population-based cohort study of one million Swedish men. Int J Epidemiol 2009;38(1):110–8.
[30] Shrier I. Muscle strength and body size and later cerebrovascular and coronary heart disease. Clin J Sport Med 2010;20:131.
[31] Ling CH, Taekema D, de Craen AFJ, Gussekloo J, Westendorp RG, Maier AB. Handgrip strength and mortality in the oldest old population: the Leiden 85-plus study. CMAJ 2010;128:429–35.