Association between Cardiorespiratory Fitness, Relative Grip Strength with Non-Alcoholic Fatty Liver Disease

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Background: Non-alcoholic fatty liver disease (NAFLD) is a common clinical syndrome with no medications for long-term management. At present, diet control and weight loss are 2 major lifestyle components to reduce the risk of NAFLD. However, other lifestyle components such as cardiorespiratory fitness (CRF) and grip strength (GS) have been neglected in research. This study was to investigate the correlation between CRF, relative GS (RGS), and NAFLD among a male study population.

Material/Methods: We screened 1126 men who underwent comprehensive health checks. The participants were divided into an NAFLD group (n=224) and a non-NAFLD group (n=902). The clinical data analyzed included anthropometry, biochemical examination, CRF measurement, and GS calculation were recorded, and the dose-response association between maximal oxygen uptake (VO$_{2}$max), RGS, and NAFLD. Stepwise logistic regression analysis was conducted to establish a predictive model of NAFLD.

Results: VO$_{2}$max <30 mL/kg·min$^{-1}$ was not associated with the risk of NAFLD (P>0.05). When VO$_{2}$max was >30 mL/kg·min$^{-1}$, the risk of NAFLD decreased obviously (P=0.007), suggesting a dose-response relationship between VO$_{2}$max and NAFLD risk. With the increase of RGS, the risk of NAFLD decreased prominently (P<0.001), which indicated a dose-response relationship between RGS and NAFLD risk. We also found that body fat percentage, body mass index, systolic blood pressure, diastolic blood pressure, total cholesterol and triglycerides were risk factors, whereas VO$_{2}$max >30 mL/kg·min$^{-1}$, RGS, and high-density lipoprotein cholesterol were protective factors for NAFLD. The area under the curve (AUC) of the predictive model of NAFLD was 0.819 (95% confidence interval [CI]: 0.790–0.847, P=0.174). The sensitivity and specificity were 80.4% and 67.8%, respectively.

Conclusions: In the male study population, VO$_{2}$max and RGS were negatively correlated with the risk of NAFLD, thus, the risk of NAFLD could thus be reduced by improving VO$_{2}$max and RGS in this population.

MeSH Keywords: Fatty Liver • Hand Strength • Rehabilitation

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Background

Non-alcoholic fatty liver disease (NAFLD) is a common clinical syndrome characterized by excessive intracellular fat deposition; it is an acquired metabolic stress liver injury closely related to insulin resistance and genetic susceptibility [1]. With the globalization trend of obesity and its related metabolic syndromes, NAFLD has gradually been recognized as an important cause of chronic liver disease [2–4]. Previous studies have shown that the prevalence of NAFLD in adults is up to 10–30% [4,5], and is strongly associated with metabolic disturbances and an increased risk of cardiovascular diseases and type 2 diabetes [6–8]. Therefore, it is of clinical value for clinicians to identify and treat the patients with NAFLD as soon as possible.

To date, no medications for the long-term management of NAFLD have been approved, and diet control and weight loss are 2 major components included in the guidelines for the prevention and management of NAFLD [9,10]. Other lifestyle components, however, are often neglected such as cardiorespiratory fitness (CRF) and grip strength (GS), which are closely associated with cardio-metabolic health [11,12]. CRF, when assessed as part of the maximal oxygen uptake (VO2max), reflects the ability of respiratory and circulatory systems, as well as the ability of muscle tissues to provide oxygen during continuous physical activity. The American Heart Association proposed that CRF can be used as a potential screening tool for the assessment of health outcomes [13]. Early studies reported that CRF at a low level was related to the risk of several chronic diseases, as well as all-cause mortality, cardiovascular disease, and cancers [13–15], while elevated CRF levels had a protective effect on health outcomes [13].

GS is a simple and practicable indicator of overall muscle strength for measuring the maximum static force that one hand can exert around a dynamometer with good retest reliability [16,17]. Research suggests that the predictive efficacy of muscle strength is superior to muscle mass in poor outcomes [18–20], and low GS has been assessed in connection with health damage and higher all-cause mortality [18–22]. In physical fitness tests, GS is often expressed as relative GS (RGS) to obtain a scientific and effective physical strength assessment. Due to its predictive validity and simplicity, GS may be a potential screening tool for clinicians to use to improve human muscle health.

Although experimental studies have reported the associations between CRF and NAFLD in animals, limited data exist in humans [23,24]. Research has focused on prevalence, all-cause mortality, and adolescent populations. In addition, few studies have evaluated the link between RGS and NAFLD risk. The objective of our investigation was to assess the correlation between CRF, RGS, and NAFLD risk in a population-based sample of male adults.

Material and Methods

Participants

Participants were recruited from the Multi-center Application Research on Fitness Test and Exercise Management project of China Health Foundation. A total of 1126 male participants were enrolled; participants underwent comprehensive health checks. The participants were divided into an NAFLD group (n=224) and a non-NAFLD group (n=902). The clinical data recorded included anthropometry, biochemical examination, CRF measurement, and GS calculations. Individuals included were 20–60 years old, from an urban population, and without cardiovascular, pulmonary, or musculoskeletal diseases.

Anthropometric indicators

The anthropometric indicators were recorded by a wireless body composition monitor (MC-180, TANITA Corp., Tokyo, Japan) and a sphygmomanometer (M500, OMRON Healthcare Co., Ltd., Kyoto, Japan). Before the body assessments, the participants were asked to fast for 3 hours, avoid strenuous activities within 24 hours, empty their bowels, and wear light clothing without accessories. The age, body fat percentage (%), body mass index (BMI) measured by weight/height (kg/m²), waist-to-hip ratio (WHR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were recorded.

Laboratory examination

The participants were not allowed to smoke or drink the day before the test, and they were asked to fast for at least 12 hours before the venous blood draw was taken (from the elbow area) in the morning. The laboratory tests included total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and fasting blood-glucose (FBG).

CRF measurement

The CRF test was carried out using the YMCA power car scheme (YMCA Submaximal Cycle Ergometer Test) [25]. According to the test requirements, for the first stage the load was 150 kg/min at 50 rpm of the rotation speed, and individuals were continuously measured 2–4 levels with moving at least 3 minutes of each stage. The stable heart rates of study participants were controlled between 110 beats per minute (bpm) and 70% of the heart rate reserve (85% of the age-predicted heart rate) in the continuous tests, and the heart rates at the 45–60 seconds...
of the 2nd and 3rd minute were recorded. If the heart rate changed more than 5 bpm, the movement was extended for 1 minute at this power. The heart rate and power of 2 points in continuous stages with stable heart rates of 110 bpm or more were selected as a straight line. The extended line of the straight line was used to determine the predicted maximum power corresponding to the age-predicted maximum heart rate, and then the VO\(_2\) max was calculated according to the standard formula:

\[
\text{GS calculation}
\]

GS was measured using a Jamar dynamometer (HK6000, Hengkangjiaye Corp., China). The study participants feet were naturally separated into an upright position, with their arms hanging down, then the dynamometers were held by one hand and the GS values were recorded [26]. The GS was detected with the dominant hand 3 times, taking the maximum value. The calculation of RGS is the ratio of GS and weight.

Diagnostic criteria

The audiovisual diagnosis of NAFLD were based on a B ultrasound diagnostic instrument (SSA-790A (Aplio XG), TOSHIBA Corp., Tokyo, Japan) with 3.5 MHz of the transducer frequency. The criteria were as follows: 1) diffuse punctate hyperechoic field near the liver area, a higher intensity of echo than in spleen and kidney, and focal hyperecho (noted in a few participants); 2) the attenuation of echo in far field and sparse light spots; 3) unclear intrahepatic tube structures; 4) mild or severe swelling of liver, and the blunted leading edge of liver.

Statistical analysis

Statistical analysis was performed using SPSS 23.0 (SPSS, Inc., Chicago, IL, USA). Measurement data were presented as the mean±standard deviation (mean±SD) or [M (Q1, Q3)] and analyzed by t-test or Mann-Whitney U test. The correlation between 2 variables was calculated using Pearson correlation. P<0.05 was considered statistically significant. The regression coefficient B was calculated using a linear model with the presence or absence of NAFLD as grouping variables, age, and weight as the control variables, other indicators as dependent variables, and VO\(_2\) max and RGS as independent variables. Then the effects of VO\(_2\) max and RGS on other indicators in the 2 groups were analyzed.

The interaction of independent variables was identified using a linear model with age and weight as the control variables, other indicators as dependent variables, VO\(_2\) max, RGS, and centralized VO\(_2\) max * centralized RGS as independent variables. After adjusting the confounding factors of the age, BMI, body fat percentage, SBP, TG, and LDL, the restrictive cubic spline (RCS) model based on logistic regression was used.

The dose-response association between VO\(_2\) max, RGS, and NAFLD were analyzed, and the quantile 5%, 25%, 75%, and 95% and the quantile 25%, 50%, and 75% as nodes of the model were selected, respectively.

Results

The baseline data of individuals

A total of 1126 male participants were included in this study that comprised 224 NAFLD cases and 902 non-NAFLD individuals, with the mean age of (36.56±8.93) years, the average BMI of (24.59±3.50), the mean VO\(_2\) max of 31.76±5.06 (range 19.60–66.15) and the mean RGS of 1.58±0.35 (range 0.56–3.02). As shown in Table 1, the results found that VO\(_2\) max was associated with the body fat percentage, BMI, WHR, TC, TG, and FBG, whereas RGS was related to the body fat percentage, BMI, WHR, DBP, TC, TG, LDL-C, HDL-C, and FBG (P<0.05). The correlations between VO\(_2\) max and various variables are presented in Table 2. For each unit increased in VO\(_2\) max, the body fat percentage of non-NAFLD individuals decreased by 0.27% on average, BMI by 1.8 kg/m\(^2\), WHR by 0.21, the log of TC by 0.08, while the reciprocal of FBG increased by 0.04 after adjusting the effect of age (P<0.05). This indicated that increased VO\(_2\) max in the non-NAFLD group can reduce the levels of body fat percentage, BMI, WHR, and FBG.

Our findings revealed that with the RGS increase of one unit, the mean body fat percentage, BMI, WHR, DBP and the logarithm of TG in the non-NAFLD group decreased by 0.52%, 0.54 kg/m\(^2\), 0.48, 0.07 mmHg, and 0.25 mg/dL, respectively (P<0.05), while body fat percentage, BMI, WHR, and TG in the NAFLD group decreased via 0.54%, 0.48 kg/m\(^2\), 0.47, and 0.15 mg/dL respectively (P<0.05). These findings suggested that elevated RGS could decrease the levels of body fat percentage, BMI, WHR, and TG in the non-NAFLD group, and body fat percentage, BMI, WHR and TG of the NAFLD group.

As displayed in Table 3, no statistical differences were found in regression coefficients of the interactive items in the linear regression model, indicating no interaction between VO\(_2\) max, RGS, and NAFLD.
### Table 1. The characteristics of the male study population.

| Variables                  | Skew  | Kurt  | $\bar{x}/s/M$ (Q1, Q3) | VO$_{\text{max}}$ | RGS   |
|----------------------------|-------|-------|-------------------------|------------------|-------|
| Age, year                  | 0.10  | 0.07  | 36.56±8.93              | -0.07**          | -0.15**|
| GS, kg                     | 0.06  | 0.17  | 38.27±6.97              | 0.03             | 0.76** |
| RGS                        | 0.32  | 0.11  | 1.58±0.35               | 0.13**           | 1     |
| VO$_{\text{max}}$, mL/kg$^{-1}$·min$^{-1}$ | 1.09  | 3.14  | 31.76±5.06              | 1.03             | 0.13** |
| Body fat percentage, %     | -0.27 | 0.31  | 21.37±6.13              | -0.23**          | -0.55**|
| BMI, kg/m$^2$              | 0.45  | 1.17  | 24.59±3.50              | -0.17**          | -0.56**|
| WHR                        | -0.36 | 0.64  | 0.93 (0.90, 0.96)       | -0.21**          | -0.52**|
| SBP, mmHg                  | 0.20  | 0.10  | 118.27±12.81            | -0.01            | -0.02  |
| DBP, mmHg                  | 0.13  | 0.07  | 74.48±10.94             | -0.08*           | -0.11**|
| TC, mg/dL                  | 0.83  | -0.18 | 4.69 (0.75)             | -0.06*           | -0.11**|
| TG, mg/dL                  | 5.54  | 0.72  | 44.46 (1.34)            | -0.19**          | -0.30**|
| LDL-C, mg/dL               | 0.31  | 0.32  | 3.23±0.90               | -0.03            | -0.07**|
| HDL-C, mg/dL               | 27.87 | -0.84 | 875.09 (2.03)           | 0.11**           | 0.23** |
| FBG, mg/dL                 | 6.32  | -1.14 | 58.73 (5.34)            | 0.05             | 0.17** |

*P<0.05; **P<0.01. Variables were carried out as log conversion. GS – grip strength; RGS – relative grip strength; VO$_{\text{max}}$ – maximal oxygen uptake; BMI – body mass index; WHR – waist-to-hip ratio; SBP – systolic blood pressure; DBP – diastolic blood pressure; TC – total cholesterol; TG – triglyceride; HDL-C – high-density lipoprotein cholesterol; LDL-C – low-density lipoprotein cholesterol; FBG – fasting blood-glucose.

### Table 2. Effects of VO$_{\text{max}}$ and RGS on male study population.

| Variables                  | $\bar{x}/s/M$ (Q1, Q3) | P     | VO$_{\text{max}}$ | RGS   |
|----------------------------|-------------------------|-------|------------------|-------|
| Non-NAFLD                  | NAFLD                   |       | Non-NAFLD       | NAFLD |
| Body fat percentage, %     | 20.29±5.97              | <0.001** | -0.27**        | -0.52**| -0.54** |
| BMI, kg/m$^2$              | 23.96±3.30              | <0.001** | -1.8**         | -0.52**| -0.48** |
| WHR                        | 0.92±0.04               | <0.001** | -0.21**        | -0.48**| -0.47** |
| SBP, mmHg                  | 116.28±12.81            | 0.009** | -0.03           | -0.04  | -0.07**|
| DBP, mmHg                  | 73.93±10.77             | 0.001** | -0.08**        | 0.05   | -0.07**|
| TC, mg/dL                  | 5.20 (4.55, 5.81)       | 0.014* | -0.08           | 0.03   | -0.06  |
| TG, mg/dL                  | 1.35 (0.94, 1.92)       | <0.001** | -0.22**        | 0.03   | -0.25**| -0.15* |
| LDL-C, mg/dL               | 3.24±0.90               | 0.571  | 0.03             | 0.03   | -0.07**|
| HDL-C, mg/dL               | 1.34 (1.16, 1.54)       | <0.001** | 0.13**         | 0.03   | 0.24** |
| FBG, mg/dL                 | 5.06 (4.74, 5.47)       | <0.001** | 0.04            | 0.01   | 0.13** |
| VO$_{\text{max}}$, mL/kg$^{-1}$·min$^{-1}$ | 31.90±5.17              | 0.06   | -             | -     | -     |
| RGS                        | 1.62±0.35               | 1.43±0.30 | <0.001**    | -     | -     |

*P<0.05; **P<0.01. NAFLD – non-alcoholic fatty liver disease; VO$_{\text{max}}$ – maximal oxygen uptake; RGS – relative grip strength; BMI – body mass index; WHR – waist-to-hip ratio; SBP – systolic blood pressure; DBP – diastolic blood pressure; TC – total cholesterol; TG – triglyceride; HDL-C – high-density lipoprotein cholesterol; LDL-C – low-density lipoprotein cholesterol; FBG – fasting blood-glucose.
Dose-response relationship between CRF, RGS, and NAFLD risk

The restricted cubic spline regression curve of VO\(_{2}\)\text{max} and NAFLD risk are shown in Figure 1. The results found that VO\(_{2}\)\text{max} <30 mL/kg\text{-}1\cdot\text{min}\text{-}1 was not associated with the risk of NAFLD (\(P>0.05\)). When VO\(_{2}\)\text{max} was >30 mL/kg\text{-}1\cdot\text{min}\text{-}1, the risk of NAFLD decreased obviously (\(P=0.007\)), suggesting a dose-response relationship between VO\(_{2}\)\text{max} and NAFLD risk.

In Figure 2, with the increase of the RGS, the risk of NAFLD decreased prominently (\(P<0.001\)), which indicated a dose-response relationship between RGS and the risk of NAFLD.

Logistic regression analysis for the risk of NAFLD

Regression analysis was used to assess the associations between NAFLD risk and the relevant indicators in Table 4.

Table 3. Effects of VO2max and RGS on general data.

| Variables               | VO\(_{2}\)\text{max} | RGS  | Centralized VO\(_{2}\)\text{max} * centralized RGS |
|-------------------------|----------------------|------|----------------------------------------------------|
| Body fat percentage, %  | –0.15**              | –0.53** | –0.03                                              |
| BMI, kg/m\(^2\)         | –0.09**              | –0.55** | –0.01                                              |
| WHR                     | –0.14**              | –0.50** | –0.03                                              |
| SBP, mmHg               | 0.002                | –0.02 | –0.03                                              |
| DBP, mmHg               | –0.05                | –0.08** | –0.03                                              |
| TC, mg/dL               | –0.04                | –0.08** | –0.01                                              |
| TG, mg/dL               | 0.02                 | 0.14 | –0.02                                              |
| LDL-C, mg/dL            | –0.02                | –0.06 | –0.03                                              |
| HDL-C, mg/dL            | 0.08*                | 0.22** | 0.004                                              |
| FBG, mg/dL              | –0.002               | –0.09** | 0.03                                               |

\(* P<0.05; \** P<0.01. VO\(_{2}\)\text{max} – maximal oxygen uptake; RGS – relative grip strength; BMI – body mass index; WHR – waist-to-hip ratio; SBP – systolic blood pressure; DBP – diastolic blood pressure; TC – total cholesterol; TG – triglyceride; HDL-C – high-density lipoprotein cholesterol; LDL-C – low-density lipoprotein cholesterol; FBG – fasting blood-glucose.

Figure 1. The dose-response relationship between VO\(_{2}\)\text{max} and non-alcoholic fatty liver disease (NAFLD) risk.

Figure 2. The dose-response relationship between relative grip strength (RGS) and non-alcoholic fatty liver disease (NAFLD) risk.

The results of single-factor logistic regression analysis showed that statistical differences were discovered in age (odds ratio [OR]=1.051, 95% CI: 1.033–1.069, \(P<0.05\)), VO\(_{2}\)\text{max} >30 mL/kg\text{-}1\cdot\text{min}\text{-}1 (OR=0.670, 95% CI: 0.577–0.777, \(P<0.001\)), RGS (OR=0.171, 95% CI: 0.106–0.275, \(P<0.001\)), body fat percentage (OR=1.212, 95% CI: 1.170–1.255, \(P<0.001\)), BMI (OR=1.335, 95% CI: 1.267–1.407, \(P<0.001\)), WHR (OR=1.373, 95% CI: 1.289–1.464, \(P<0.001\)), SBP (OR=1.083, 95% CI: 1.069–1.098, \(P<0.001\)), DBP (OR=1.023, 95% CI: 1.009–1.037,
### Table 4. Logistic regression analysis for the risk of NAFLD.

| Variables                        | Single factor | Multivariate |
|----------------------------------|---------------|--------------|
|                                  | OR 95% CI     | OR 95% CI    |
| Age, year                        | 1.051*        | 0.586–0.802  |
| VO\(\text{max} > 30 \text{ mL/kg}^{-1}\cdot\text{min}^{-1}\) | 0.670***      | 0.686***     |
|                                 | 0.577–0.777   | 0.586–0.802  |
| RGS                              | 0.670***      | 0.586–0.802  |
|                                 | 0.577–0.777   | 0.586–0.802  |
| Body fat percentage, %           | 1.212***      | 1.034–1.152  |
|                                 | 1.170–1.255   | 1.034–1.152  |
| BMI, kg/m\(^2\)                 | 1.335***      | 1.244–1.388  |
|                                 | 1.267–1.407   | 1.244–1.388  |
| WHR                              | 1.373***      | 1.289–1.464  |
|                                 | 1.289–1.464   | 1.289–1.464  |
| SBP, mmHg                        | 1.270***      | 1.067–1.248  |
|                                 | 1.108–1.457   | 1.067–1.248  |
| DBP, mmHg                        | 1.292***      | 1.010–1.214  |
|                                 | 1.184–1.408   | 1.010–1.214  |
| TC, mg/dl                        | 1.203***      | 1.039*       |
|                                 | 1.009–1.037   | 1.018–1.061  |
| TG, mg/dl                        | 1.292***      | 1.107*       |
|                                 | 1.184–1.408   | 1.018–1.061  |
| LDL-C, mg/dl                     | 0.954         | 0.332***     |
|                                 | 0.811–1.123   | 0.184–0.599  |
| HDL-C, mg/dl                     | 0.263***      | 0.332***     |
|                                 | 0.151–0.459   | 0.184–0.599  |
| FBG, mg/dL                       | 1.227***      | 1.120–1.345  |

*\(P<0.05\); ** \(P<0.01\); *** \(P<0.001\). NAFLD – non-alcoholic fatty liver disease; OR – odds ratio; CI – confidence interval; RGS – relative grip strength; VO\(\text{max}\) – maximal oxygen uptake; BMI – body mass index; WHR – waist-to-hip ratio; SBP – systolic blood pressure; DBP – diastolic blood pressure; TC – total cholesterol; TG – triglyceride; HDL-C – high-density lipoprotein cholesterol; LDL-C – low-density lipoprotein cholesterol; FBG – fasting blood-glucose.

\(P<0.001\), TC (OR=1.270, 95% CI: 1.108–1.457, \(P<0.001\)), TG (OR=1.292, 95% CI: 1.184–1.408, \(P<0.001\)), and HDL-C (OR=0.263, 95% CI: 0.151–0.459, \(P<0.001\)). There were differences in VO\(\text{max} > 30 \text{ mL/kg}^{-1}\cdot\text{min}^{-1}\) (OR=0.686, 95% CI: 0.586–0.802, \(P<0.001\)), RGS (OR=0.642, 95% CI: 0.503–0.842, \(P<0.001\)), body fat percentage (OR=1.091, 95% CI: 1.034–1.152, \(P<0.01\)), BMI (OR=1.314, 95% CI: 1.244–1.388, \(P<0.001\)), SBP (OR=1.085, 95% CI: 1.073–1.097, \(P<0.01\)), DBP (OR=1.039, 95% CI: 1.018–1.061, \(P<0.05\)), TC (OR=1.154, 95% CI: 1.067–1.248, \(P<0.01\)), TG (OR=1.107, 95% CI: 1.010–1.214, \(P<0.05\)), and HDL-C (OR=0.332, 95% CI: 0.184–0.599, \(P<0.001\)) on the basis of stepwise logistic regression analysis. It was indicated that body fat percentage, BMI, SBP, DBP, TC, and TG were risk factors, and VO\(\text{max} > 30 \text{ mL/kg}^{-1}\cdot\text{min}^{-1}\), RGS, and HDL-C were protective factors for NAFLD.

The predictive model of NAFLD was established using the variables screened by stepwise logistic regression analysis. The receiver operating characteristic (ROC) curve for predicting the risk of NAFLD is shown in Figure 3. The area under the curve (AUC) was 0.819 (95% CI: 0.790–0.847, \(P=0.174\)). The sensitivity and specificity were 80.4% and 67.8%, respectively.

![Figure 3. The receiver operating characteristic curve for predicting the risk of non-alcoholic fatty liver disease (NAFLD).](image-url)
Discussion

In this present study, we assessed the correlation between CRF, RGS, and the risk of NAFLD in a population-based sample of male adults. The key findings revealed that the risk of NAFLD gradually decreased with the increase of VO\textsubscript{2max} (>30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}) and RGS. In addition, we also found that body fat percentage, BMI, SBP, DBP, TC, and TG were risk factors, and VO\textsubscript{2max} > 30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}, RGS, and HDL-C were protective factors for NAFLD. The AUC of the predictive model of NAFLD was 0.819 (95% CI: 0.790–0.847, *P*=0.174). The sensitivity and specificity were 80.4% and 67.8%, respectively.

NAFLD is one of the most common chronic liver diseases in numerous Asia-Pacific countries including China [27] NAFLD encompasses a wide range of diseases from simple steatosis, non-alcoholic steatohepatitis, fibrosis, and even cirrhosis [28]. NAFLD as a public health concern that is predictive of cardiovascular diseases and greater mortality [29,30]. Previous studies discovered that lower VO\textsubscript{2max} levels were associated with poor outcomes of several chronic diseases, while studies on NAFLD have been rarely reported. To the best of our knowledge, previous investigations between CRF and NAFLD mainly focused on the correlation. In our study, for each one unit increase in VO\textsubscript{2max}, the body fat percentage of non-NAFLD individuals decreased by 0.27% on average, BMI by 1.8 kg/m\textsuperscript{2}, WHR by 0.21, and the log of TC by 0.08, whereas the reciprocal of FBG increased by 0.04 after adjusting the effect of age. We discovered when VO\textsubscript{2max} was > 30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}, the risk of NAFLD decreased, indicating elevated VO\textsubscript{2max} levels may decrease the NAFLD risk.

Interestingly, liver and muscle, as active endocrine organs, can secrete substances with metabolic effects [31,32]. Early studies mentioned that NAFLD and sarcopenia may have a possible connection with common pathogenesis such as insulin resistance and chronic inflammation [33–35]. Low muscle mass is a common clinical manifestation in patients with liver cirrhosis which is related to the morbidity and mortality. However, increased muscle mass cannot prevent the decrease in muscle strength, and low muscle mass is also not a leading cause of the inverse relation between muscle strength and mortality [36]. Although some studies have focused on muscle mass, there are no conclusive statements to explain the muscle status in patients with NAFLD. Herein, we investigated the direct relationship between RGS and NAFLD risk. When RGS was increased by one unit, the mean body fat percentage, BMI, WHR, DBP, and the logarithm of TG in the non-NAFLD group decreased by 0.52%, 0.54 kg/m\textsuperscript{2}, 0.48, 0.07 mmHg, and 0.25, respectively, while body fat percentage, BMI, WHR, and TG in the NAFLD group decreased via 0.54%, 0.48 kg/m\textsuperscript{2}, 0.47, and 0.15 mg/dL, respectively. Furthermore, a dose-response relationship between RGS and the risk of NAFLD was founded in our research, and the risk of NAFLD decreased with an increase of the RGS. This indicated that increasing muscle strength may reduce the risk of NAFLD. We also found significant differences in VO\textsubscript{2max} > 30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}, RGS, body fat percentage, BMI, SBP, DBP, TC, TG, and HDL-C. These findings indicated that body fat percentage, BMI, SBP, DBP, TC, and TG were risk factors, and VO\textsubscript{2max} > 30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}, RGS, and HDL-C were protective factors for NAFLD. In addition, a predictive model of NAFLD was established and the AUC of ROC curve for predicting NAFLD was 0.819. This suggested that this model could be a predictive tool for patients with NAFLD.

The strengths of the study were that we assessed the effects of CRF and RGS on the risk of NAFLD in a population-based sample of male adults. We found a dose-response relationship between VO\textsubscript{2max}, RGS and NAFLD risk that may be an effective method to predictive the risk of NAFLD. There were some limitations to our study that warranted caution for interpreting the data. Our study included only 1126 male participants who voluntarily participated in the study, which may present some recruitment bias. The value of VO\textsubscript{2max} was estimated with a submaximal cycle ergometer test. Additionally, the behavioral habits, nutritional status, socio-economic status, and health care may have confounded the association between the variables under examination.

Conclusions

In summary, our findings suggested a dose-response relationship between VO\textsubscript{2max}, RGS, and NAFLD risk. With the increase of VO\textsubscript{2max} (>30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}) and RGS, the risk of NAFLD gradually decreased. VO\textsubscript{2max} and RGS were negatively correlated with the risk of NAFLD, which could be reduced by improving VO\textsubscript{2max} and RGS in this male study population. In addition, we also found that body fat percentage, BMI, SBP, DBP, TC, and TG were risk factors, and VO\textsubscript{2max} > 30 mL/kg\textsuperscript{-1}·min\textsuperscript{-1}, RGS, and HDL-C were protective factors for NAFLD. Thus, CRF and physical exercise should be emphasized to reduce the burden of NAFLD at the population level.

Conflict of interests

None.
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