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*Article*

# Variation Tendency of CVD Risk Factors in Blood According to Age and Relative Grip Strength among Different Populations Based on Bayesian Probabilistic Approach: A Cross-Sectional Study from Jiangsu Province's Data of China Physical Fitness Surveillance

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**Abstract:** *Background:* Cardiovascular disease (CVD) has been one of the leading causes of death and disability-adjusted life years lost worldwide. Blood pressure, lipid, and cholesterol are good predictors of CVD risk and correspond upon age and physical fitness. However, few studies have explored the variation trend of CVD risk factors across different populations upon age and their muscle strength. *Objective:* to analysis the variation tendency of CVD risk factors in blood according to age and relative grip strength among different populations. *Method:* 25363 participants were recruited in this cross-sectional study and 24709 were included in the analysis. A logistic regression and a Bayesian probabilistic analysis based on Markov Chain Monte Carlo (MCMC) Modeling is conducted to build probability prediction models of hypertension, hyperlipidemia, and hypercholesterolemia according to age, relative grip strength, body weight conditions, and physical activity levels. Results: 1) age might be the main influence factor of hypertension, which is regarded as one of the primary CVD risk factors. However, although keeping a high level of physical activity might have positive effect on preventing hypertension because that individuals with normal body weight and higher physical activity shows a lower probability of being diagnosed with hypertension, it might could not prevent individuals from getting hypertension with age. 2) After 60, individuals of normal body weight seem more likely to have hyperlipidemia than those are overweight or obese. 3) Larger relative grip strength might not be able to offset the negative effects of obesity, overweight and physical inactivity on hyperlipidemia. 4) The probability of getting hypercholesterolemia varies less with age and relative grip strength. *Conclusion:* Body weight management and keeping high levels of physical activity are recommended at any age. It might benefit to increase some bodyweight after 60 years old.

**Keywords:** Bayesian; cardiovascular disease; CVD; cross-sectional; logistic regression

## 1. Introduction

Cardiovascular disease (CVD) has been one of the leading causes of death and disability-adjusted life years lost worldwide, accounting for about one-third of all deaths worldwide[1]. In China, CVD is the leading cause of death and disease burden [2-4] and attributing two out of five deaths[3]. The mortality, incidence, and prevalence of CVD, which mainly induced by hypertension, hyperlipidemia, and hypercholesterolemia, have been increasing over the past 30 years, and the number of CVD patients has reached 290 million in recent years[3].

Previous studies have demonstrated that blood pressure, lipid, and cholesterol are good predictors of CVD risk and correspond upon age and physical fitness. For example, blood pressure not only varies physiologically in response to changes in demand that accompany normal physical activities and in predictable trends driven by the circadian rhythm [5], but also increases upon age even in normotensive individuals [6]. This variation in blood pressure has been regarded as a risk factor for adverse cardiovascular outcomes and mortality. Besides, previous also claimed that hyperlipidemia is associated with premature CVD, increasing the risk of primary CVD despite preventive measures [7] since the blood lipid would change during physical growth and sexual maturation and significantly differ within age stages [8]. Moreover, some cross-sectional studies and cohort studies have found that the blood cholesterol, which would probably increase upon age [9,10], would result in worsening of the CVD risk, and a higher blood cholesterol would be correlated with an increased risk of major CVD among the Chinese population [11].

However, the factors which would affect the CVD risk are complex. Previous studies claimed that a comprehensive control of multiple cardiovascular risk factors to reduces cardiovascular risk is necessary but difficult to achieve [12]. The reason might be that these factors are from not only physiological and biochemical perspectives but also from physical fitness condition and lifestyle. For example, several previous cohort studies have discussed the CVD risk and all-cause mortality, confirming that the relationship between the body weight conditions of overweight and obesity and the increased CVD risk and all-cause mortality compared with normal weight [13,14]. Furthermore, there have been studies that compared obesity individuals with non-obese individuals, claiming that obesity has a better effect on predicting cardiovascular diseases[15]. When it comes to the lifestyle, previous studies have verified the health benefits of physical activity for people of all ages, fitness levels, and sociodemographic backgrounds [16-19]. Physical activity level is central components of public health promotion efforts [16,20]. The body fitness condition, especially the muscle strength of an individual, is also an influence factor of the CVD risk. Many previous studies have explored the association between CVD and muscle strength condition, among which the grip strength is mostly applied. For example, a report published in 2015 claimed that the reduced grip strength, and therefore muscle strength, was linked to increased risk of death among individuals with cardiovascular disease [21], and a prospective study published in 2021 demonstrated that low grip strength was associated with a high risk of major CVD incidence, CVD mortality, and all-cause mortality among patients with hypertension [22]. Moreover, since the muscle strength is associated with the lean body mass, which is mostly depends on the body mass index, to a large extent, the relative grip strength (absolute strength corrected for a measure of body size such as BMI) has been recommended[23,24]. A study conducted in 2016 verified that increased relative handgrip strength was associated with a better profile of cardiovascular health biomarkers and would be a useful public health measure of muscle strength [25]. Other previous studies also suggested that the predictive efficacy of muscle strength is superior to muscle mass, and low relative grip strength has been assessed in connection with health damage and higher all-cause mortality with high predictive validity and simplicity [26].

Being similar with the physiological and biochemical parameters, muscle strength, which could be represented by relative grip strength, would also be different within populations with different physically active levels and body weight. Previous studies have demonstrated that physically inactive individuals, especially overweighted and elder people might be more likely to suffer from decrease in muscle strength [27-29]. The physiological mechanism might from two sides, one is the atrophy and quantity reduce of muscle fibers which induced by the higher rate of muscle protein breakdown in physically inactive populations, the other is the decrease in the ability of nervous system to recruit large motor units. Previous studies have demonstrated that progressive declines in muscle mass and strength was strongly associated with long-term mortality and cardiovascular events [30]. At the same time, the decline in muscle quantity has also been verified to have association with CVD events.

Most previous studies have focused on analyzing the risk of CVD in specific populations and the influence factors that affect the CVD risk, while few studies have explored the variation trend of CVD risk across different populations upon age and their muscle strength. At the same time, most previous studies based on probabilistic analyses could only be interpreted as the frequency of CVD in a certain population, or the probability of CVD in a large number of replicates. However, for individuals, once diagnosed with CVD, it means an increase in their medical costs and decrease in quality of life, and there is no chance of repetition. Therefore, from the perspective of individual prevention of CVD, more attention should be paid to the variation trend of CVD risk.

Mathematically speaking, there are only two results for an individual is diagnosed with CVD or not, diagnosed or not, under a specific age, body weight, and physical fitness condition. The diagnosis results would be dichotomously distributed. Therefore, the Bayesian probabilistic approach could be feasible in combination with clinical practice, in this method, a large number of diagnosis data could be seen as the prior probability of CVD events, through continuous accumulation of diagnosis results, the CVD risk of an induvial under a certain age, body weight, and physical fitness condition and its variation trend could be calculated. It could bring new value and inspiration for clinical guiding of CVD prevention and patient education.

The China Physical Fitness Surveillance (CPFS) conducted a series of nationwide surveys since 2000 to monitor physical health in the Chinese population. This study used the Jiangsu province's data of CPFS in 2015, aiming to analysis the variation tendency of CVD risk factors in blood according to age and relative grip strength among different populations through Bayesian probabilistic approach.

## 2. Methods

### *2.1. Study population*

The study investigated adults 18 years and older, all participants provided written informed consent.

#### 2.1.1. Eligibility criteria

The eligibility criteria of this study were as follows: (1) adults from 18 to 90 years old; (2) without any physical disorders; (3) without any clinical exercise contraindication; (4) without any cognitive disorder; (4) Body mass index (BMI)≥18.5. In this study, the body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters.

#### 2.1.2. Exclusion criteria

The exclusion criteria of this study were as follows: (1) individual younger than 18 years old or older than 90 years old; (2) with physical disorder or clinical immobilization; (3) with clinical exercise contraindication; (4) with cognitive disorders; (5) Body mass index (BMI)<18.5.

#### 2.1.3. Ethics

The study was approved by the Institutional Ethics Committee of Ningbo University (NO. 20211145).

### *2.2. Data Collection*

All participants completed a standardized questionnaire to capture information on demographics, socioeconomic position, medical history, physical activity, and medication use. At the time of interview, anthropometry, blood pressure, and electrocardiographic measurements were obtained. Bodyweight and height were measured without shoes while wearing light clothes and the abdominal circumference was measured as the narrowest circumference between the lower rib margin and anterior superior iliac crest above the umbilicus at exhalation. Participants had their systolic blood pressure (SBP) and diastolic blood pressure (DBP) measured after 5 minutes of rest in a seated position with their arms, back, and feet supported. The first and fifth Korotkoff sounds were registered to indicate SBP and DBP, respectively. Two blood pressure measures were obtained, and the mean was calculated.

Blood samples were obtained from all participants through venipuncture. Serum concentrations of glucose, total cholesterol, HDL cholesterol, and triglycerides were determined using the enzymatic method.

*2.3. Definitions*

The relative grip strength was defined as the results of grip strength test in kilogram divided by the body mass index (BMI) [31,32], whereas the unit of age was set in years.

According to the Criteria of Weight for Adults enacted by the National Health Commission of the People's Republic of China, BMI<18.5 (kg/m$^2$) was defined as underweight, 18.5≤BMI<24.0 (kg/m$^2$) was defined as normal body weight, 24.0≤BMI<28.0 (kg/m$^2$) was defined as overweight, and BMI≥28.0 (kg/m$^2$) was defined as obesity[33]. Number 1 would be regarded as the bodyweight condition of overweight and obesity, whereas the number 0 would be regarded as the bodyweight condition of normal bodyweight.

Level of physical activity (PAL) was defined as the result of the total energy expenditure (TEE) divided by the basal energy expenditure (BEE) in 24 hours[34,35]. There were three categories of PAL in this study which were low (PAL＜1.69, represented by the number 1), moderate (1.69≤PAL<2.00, represented by the number 2), and high (PAL≥2.00, represented by the number 3) [36,37] .

$$\boldsymbol{PAL = \frac{TEE}{BEE}}$$

Hypertension was defined as SBP ≥ 140 mmHg, DBP ≥ 90 mmHg, or self-reported use of blood pressure lowering medication. Hyperlipidemia was defined as triglycerides ≥ 150 mg/dL (≥ 1.7 mmol/L). Hypercholesterolemia was defined as total cholesterol ≥ 200 mg/dL (≥ 5.18 mmol/L) or self-reported use of lipid lowering therapy [38].

*2.4. Statistical analysis*

The Microsoft Office Excel (Version 16.0, Microsoft, IL, USA) was applied to record, store, and preprocess the original data, and the Microsoft Visual Code Studio (Version 1.64.2, Microsoft, IL, USA) was used to analyze the statistic and make the Markov Chain Monte Carlo (MCMC) modeling based on the Python language (Version 3.6.8). The Jamovi computer software (Version 23, Jamovi project, https://www.jamovi.org) would be used to make the logistic regression for binary outcomes. The original data and the analysis code would be provided in the Supplementary file of the study.

2.4.1. Logistic Regression

A logistic function was made for calculate the probability of being diagnosed with cardiovascular disease in a certain condition (age or strength). The condition of bodyweight would be set as a dichotomous in which 0 represented the participant was normal weight and 1 represented the participant was overweight or obesity, whereas the level of physical activity was set as an ordinal variable in which 1 was regarded as a low-level physical activity, 2 was regarded as a moderate-level physical activity, and 3 was regarded as high-level physical activity. The likelihood ratio test and checking of each regression model would be conducted, whereas the pseudo-R-squared of each regression model would also be calculated. The logistic function was set as follows.

$$p(x) = \frac{1}{1 + e^{\alpha+\beta x}}$$

Where $x$ was the age or the ratio of grip strength and BMI, whereas $\alpha$ and β were the characteristic parameters of the logistic function. Moreover, $\alpha$ represented the position of change and the β described the how fast the logistic function changed from 0 to 1.

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2.4.2. Markov Chain Monte Carlo (MCMC) Modeling

The PyMC library in Python 3 was used to modeling the MCMC process. The prior probability of $\alpha$ and $\beta$ would be set as normal distributions with the initial value that equaled to 0. The initial value of the would be set as TRUE when the patient was diagnosed with disease. Besides, the MCMC model was constructed by three parameters which were $\alpha$, $\beta$, and the Bernoulli random variable they correspond to. Lastly, the number of samples would be set as 200,000.

## 3. Results

### *3.1. Characteristics of study population*

The flow diagram of the participants' screening process was presented in Figure 1 and the characteristics of the study population was provided in Table 1 by frequency and percentage of each group and subgroup. The mean values and their upper and lower limits of 95% confident interval of age and grip/BMI, which were target parameters in this study, would also be calculated and provided.

According to Figure 1, 24709 participants were screened and assigned for the final analysis of the variation tendency of cardiovascular disease risk according to age, 24664 participants were screened and assigned for the final analysis of the variation tendency of cardiovascular disease risk according to relative grip strength. The distribution of the participants in different population were showed in Figure 2.

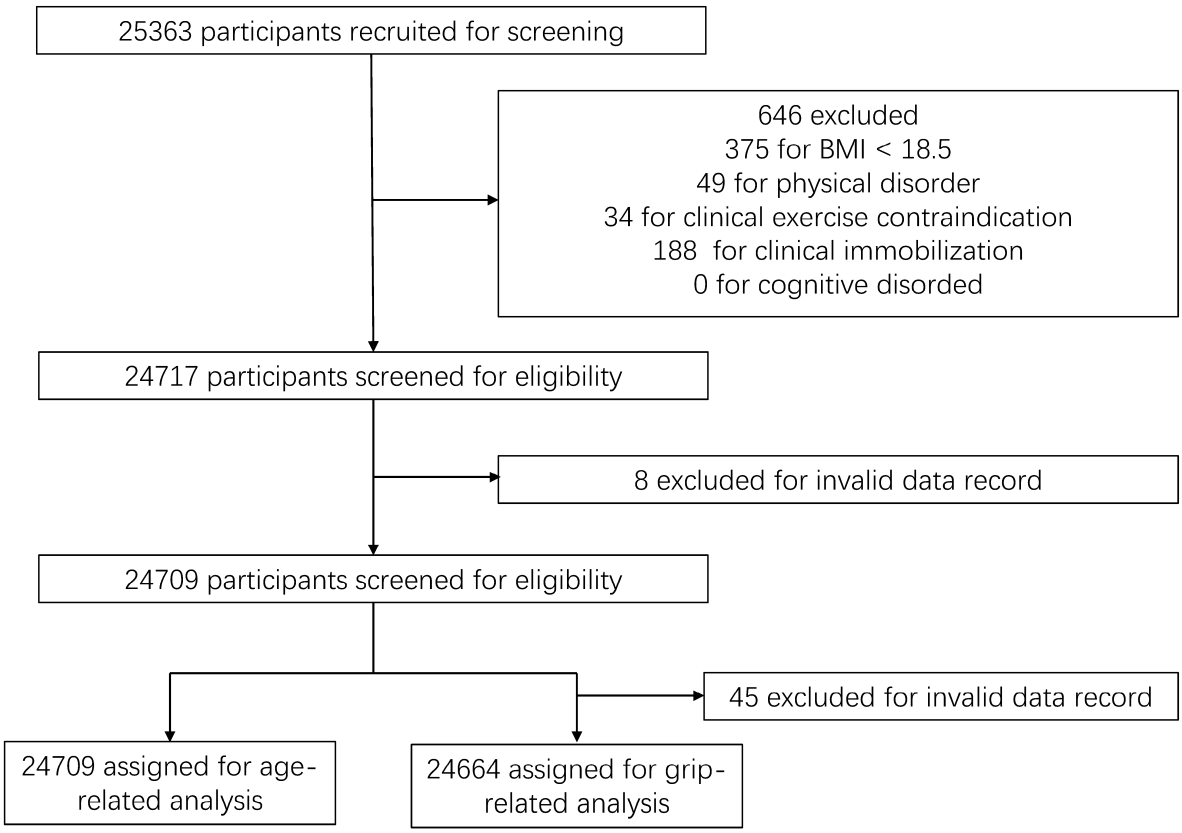


**Figure 1.** The flow diagram of the participants' screening process.

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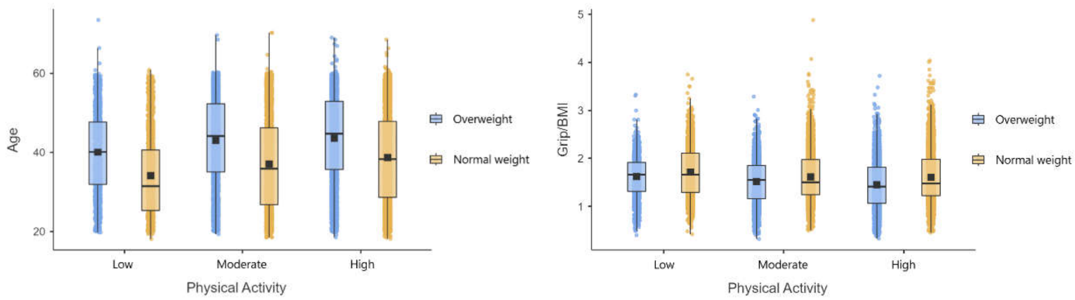
**Table 1.** Characteristics of study population.

| | Items | Physical Activity Level | Number | Percentage | Mean | 95% CI | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Age (years) | Total | | 24709 | 100% | 39.96 | 39.81 | 40.1 |
| | Overweight or obesity (BMI⩾24) | Total | 11126 | 45.03% | 43.02 | 42.82 | 43.22 |
| | | Low | 1401 | 5.67% | 40.09 | 39.55 | 40.63 |
| | | Moderate | 3688 | 14.93% | 43.1 | 42.76 | 43.44 |
| | | High | 6037 | 24.43% | 43.65 | 43.39 | 43.92 |
| | Normal weight (18.5⩽BMI<24) | Total | 13583 | 54.97% | 37.44 | 37.25 | 37.64 |
| | | Low | 1931 | 7.81% | 34.11 | 33.64 | 34.58 |
| | | Moderate | 4809 | 19.46% | 37.05 | 36.72 | 37.37 |
| | | High | 6843 | 27.69% | 38.66 | 38.39 | 38.94 |
| | Hypertension | | 2469 | 9.99% | 48.62 | 48.27 | 48.97 |
| | Hyperlipidemia | | 1489 | 6.03% | 46.83 | 46.36 | 47.3 |
| | Hypercholesterolemia | | 570 | 2.31% | 46.06 | 45.31 | 46.8 |
| Grip/BMI | Total | | 24663 | 100% | 1.56 | 1.56 | 1.57 |
| | Overweight or obesity (BMI⩾24) | Total | 11103 | 45.02% | 1.49 | 1.48 | 1.5 |
| | | Low | 1400 | 5.68% | 1.62 | 1.59 | 1.64 |
| | | Moderate | 3672 | 14.89% | 1.52 | 1.5 | 1.53 |
| | | High | 6031 | 24.45% | 1.45 | 1.44 | 1.46 |
| | Normal weight (18.5⩽BMI<24) | Total | 13560 | 54.98% | 1.62 | 1.61 | 1.63 |
| | | Low | 1925 | 7.81% | 1.71 | 1.69 | 1.74 |
| | | Moderate | 4799 | 19.46% | 1.61 | 1.6 | 1.63 |
| | | High | 6836 | 27.72% | 1.6 | 1.59 | 1.61 |
| | Hypertension | | 2464 | 9.99% | 1.51 | 1.49 | 1.52 |
| | Hyperlipidemia | | 1483 | 6.01% | 1.58 | 1.56 | 1.61 |
| | Hypercholesterolemia | | 566 | 2.29% | 1.61 | 1.57 | 1.65 |




(a) (b)

**Figure 2.** Distribution of the participants in different population (the tag overweight included populations of overweight and obesity). (a) Age-related; (b) Grip/BMI-related.

*3.2. Logistic regression*

The results of logistic regression were presented in Table 2. According to the results in Table 1, all models constructed by age (years), bodyweight condition, and PAL for logistic regressions of hypertension, hyperlipidemia, and hypercholesterolemia had a high validation with all P-values showed a statistical significance, whereas the validation of the model constructed by relative grip strength, bodyweight condition, and PAL in logistic regression in hypertension and coronary heart disease didn't show a high validation.

The receiver operating characteristic curves were presented in Figure 3 and Figure 4, and the area under curves (AUC) were provided in Table 1. According to the results, the model constructed by age (years), bodyweight condition, and PAL have a moderate effect in the risk prediction of the hypertension (AUC=0.766) and hyperlipidemia (AUC=0.743)

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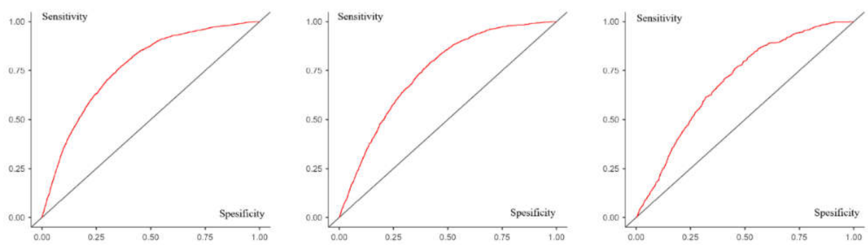
and a low effect in risk prediction of hypercholesterolemia (AUC=0.696). Besides, the model constructed by relative grip strength, bodyweight condition, and PAL had a low effect in the risk prediction of hypertension (AUC=0.650), hyperlipidemia (AUC=0.682), and hypercholesterolemia (AUC=0.641).

**Table 2.** Results of Logistic regression.

| Outcome | Model Variables | P | Likelihood Ratio Test Accuracy | Specificity | Sensitivity | AUC | Pseudo-$R^2$ McF | CS | N | Model Checking $\chi^2$ | P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hypertension | Age | <.001 | 0.900 | 1.000 | 0.001 | 0.766 | 0.129 | 0.080 | 0.168 | 2063 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | 0.003 | | | | | | | | | |
| | Grip/BMI | 0.008 | 0.900 | 1.000 | 0.000 | 0.650 | 0.046 | 0.029 | 0.061 | 730 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | 0.083 | | | | | | | | | |
| Hyperlipidemia | Age | <.001 | 0.940 | 1.000 | 0.000 | 0.743 | 0.092 | 0.041 | 0.112 | 1034 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | <.001 | | | | | | | | | |
| | Grip/BMI | <.001 | 0.094 | 1.000 | 0.000 | 0.682 | 0.054 | 0.024 | 0.066 | 600 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | <.001 | | | | | | | | | |
| Hypercholesterolemia | Age | <.001 | 0.097 | 1.000 | 0.000 | 0.696 | 0.050 | 0.013 | 0.057 | 258 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | <.001 | | | | | | | | | |
| | Grip/BMI | <.001 | 0.097 | 1.000 | 0.000 | 0.641 | 0.027 | 0.007 | 0.031 | 137 | <.001 |
| | Bodyweight | <.001 | | | | | | | | | |
| | PAL | 0.015 | | | | | | | | | |

CS: Cox and Snell; McF: McFadden; N: Nagelkerke; PAL: Physical activity level; AUC: area under curve




(a) (b) (c)

**Figure 3.** The ROC curves of age-related logistic regression. (a) Hypertension; (b) Hyperlipidemia; (c) Hypercholesterolemia.

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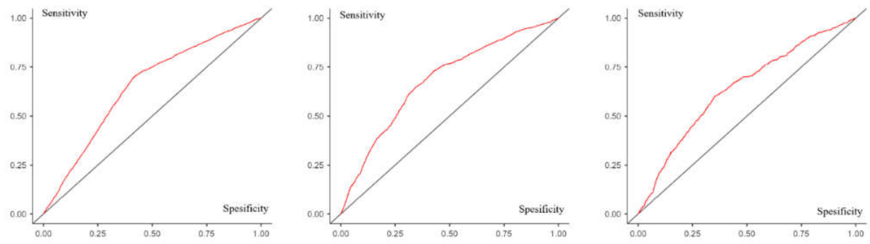


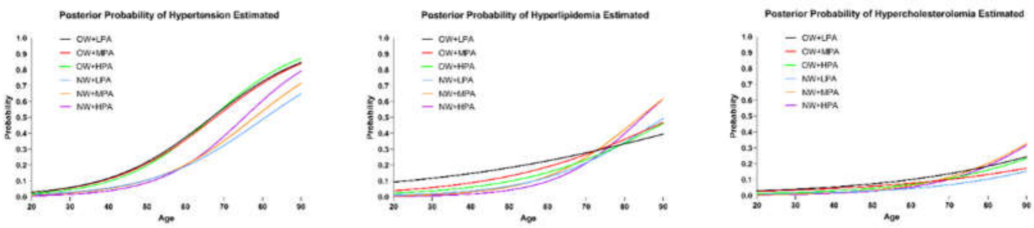

(a) (b) (c)

**Figure 4.** The ROC curves of Grip/BMI-related logistic regression. (a) Hypertension; (b) Hyperlipidemia; (c) Hypercholesterolemia.

### *3.2. Markov Chain Monte Carlo (MCMC) Modeling*

#### 3.2.1. Variation Tendency of CVD Risk according to Age

The results of the MCMC modeling for the variation tendency of CVD risk according to age is provided in Figure 5. According to the results, firstly, the probability of being diagnosed with hypertension, hyperlipidemia, and hypercholesterolemia would be increase upon age. Second, compared to overweighted and obese individuals, individuals with normal body weight would have lower probability to get hypertension in all levels of physical activity. Third, after 70 to 80 years of age, individuals with normal body weight might have a higher risk of hyperlipidemia than those are overweighted or obese, especially normal body-weighted population with high physical activity level. Fourth, there seems no significant difference within populations in different body weight conditions and physical activity level in the probability of being diagnosed with hypercholesterolemia upon different age.




(a) (b) (c)

**Figure 5.** Curves of age-related CVD probability change (OL: overweight/obesity and low level of physical activity; OM: overweight/obesity and moderate level of physical activity; OH: overweight/obesity and high level of physical activity; NL: normal body weight and low level of physical activity; NM: normal body weight and moderate level of physical activity; NH: normal body weight and high level of physical activity). (a) Hypertension; (b) Hyperlipidemia; (c) Hypercholesterolemia.

#### 3.2.2. Variation Tendency of CVD Risk according to Relative Grip Strength

The results of the MCMC modeling for the variation tendency of CVD risk according to relative grip strength is provided in Figure 5. According to the results, firstly, the probability of being diagnosed with hypertension, hyperlipidemia, and hypercholesterolemia would be almost unchanged within relative grip strength. Second, for overweight, obese, and physically inactive individuals, an increase in relative grip strength might not indicate a reduction in the probability of being diagnosed with hyperlipidemia since the curves of OL, OM, OH, and NL still rise with the increase in relative grip strength. Third, there seems no significant difference within populations of different relative grip strength in different body weight conditions and physical activity level in the probability of being diagnosed with hypercholesterolemia.

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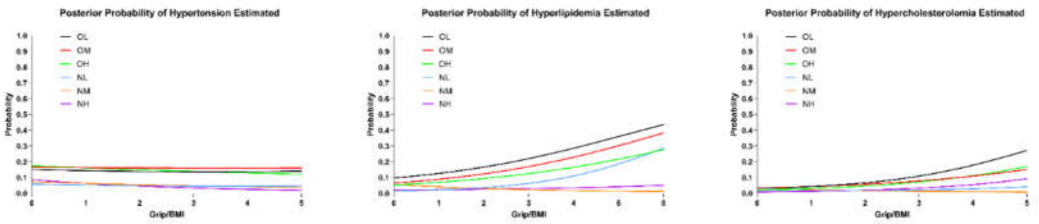


(a) (b) (c)

**Figure 6.** Curves of Grip/BMI-related CVD probability change (OL: overweight/obesity and low level of physical activity; OM: overweight/obesity and moderate level of physical activity; OH: overweight/obesity and high level of physical activity; NL: normal body weight and low level of physical activity; NM: normal body weight and moderate level of physical activity; NH: normal body weight and high level of physical activity). (a) Hypertension; (b) Hyperlipidemia; (c) Hypercholesterolemia.

## 4. Discussion

This study analyzed the variation tendency of CVD risk factors in blood according to age and relative grip strength among different populations with the novelty of using the Bayesian probabilistic approach. The main findings are as follows, above all, age might be the main influence factor of hypertension, which is regarded as one of the primary CVD risk factors. However, although keeping a high level of physical activity might have positive effect on preventing hypertension because that individuals with normal body weight and higher physical activity shows a lower probability of being diagnosed with hypertension, a higher level of physical activity might could not prevent individuals from getting hypertension with age. Secondly, a interesting and new finding from this study is that, after 60, individuals of normal body weight seem more likely to have hyperlipidemia than those are overweight or obese. Thirdly, a larger relative grip strength might not be able to offset the negative effects of obesity, overweight and physical inactivity on hyperlipidemia. Lastly, the probability of getting hypercholesterolemia varies less with age and relative grip strength, indicating that relative grip strength might not be a main influence factor of hypercholesterolemia.

According to the results of MCMC modeling, age might be the main influence factor of hypertension, which is regarded as one of the primary CVD risk factors. This result has been verified by many previous studies. For example, a study published in 1994 claimed that the magnitude of change in blood pressure was modulated by age and fitness level[39] and an interview survey conducted in 2019 also demonstrated that the increased odd of hypertension is dependent on age and BMI[40]. Moreover, a brief review made in 2020 suggested that understanding age-specific differences in sympathetic neural control of blood pressure is important in the prevention and/or risk reduction of cardiometabolic disorders for both men and women[41]. Nevertheless, it could also be seen in the MCMC modeling result, although keeping a high level of physical activity might have positive effect on preventing hypertension because that individuals with normal body weight and higher physical activity shows a lower probability of being diagnosed with hypertension, a higher level of physical activity might could not prevent individuals from getting hypertension with age. Physical exercise has been verified to have positive effect on prevent aged and middle-aged from getting hypertension, in 1999, a clinic cohort study demonstrated that there was a clinically significant reduction in blood pressure being produced with the combination of various exercises and older hypertensive individuals experienced smaller reductions in blood pressure than younger counterparts[42]. The potential mechanism might be that age would not affect the increased blood pressure response to exercise in essential hypertensive patients but the greater the severity of hypertension, the greater the increase in SBP during exercise, whereas elderly individuals with physical exercise would not have an enhanced blood pressure response[43]. However, some previous studies concluded the contrast opinion, a study conducted by Li's team in 2019 claimed that physical exercise could prevent hypertension and disrupted the correlation between the dynamic changes of vascular sympathetic activity and age-related elevation of blood pressure during the development period of hypertension[44]. The heterogeneity might come from the study protocols since the study of Li's team used animal model.

This study has an interesting and new finding, which is that after 60, individuals of normal body weight seem more likely to have hyperlipidemia than those are overweight or obese. This phenomenon might be induced by other probable mechanisms. For example, with the increase of age, the elderly's ability to metabolize heavy metals would decrease, a cross-sectional study published in 2021 found that there was a linear associations of blood lead levels with hyperlipidemia and mixed hyperlipidemia were found in community older adults [45]. Besides, the function of other metabolic organs would also decline with the increase of age, leading to elevated blood lipids in the elderly. A retrospective, cross-sectional, cohort study, which conducted in 2016, demonstrated that the highest prevalence of hyperlipidemia was in nephrotic syndrome, followed by primary/idiopathic hyperlipidemia and diabetes mellitus[46]. However, the casual relationship between hyperlipidemia and metabolic organs has not been explained clearly. For example, a study published in 2001 claimed that obesity alone might not result in glomerular hyperfiltration or renal dysfunction, but obesity associated with hypertension or hyperlipidemia may accelerate renal damage [47]. Therefore, further study should explore the mechanism from physiological and biochemical prospective to explain the phenomenon and make new regression model to predict the risk of hyperlipidemia in elderly population.

There has been an emerging amount of data suggesting that lipid metabolism plays an important role in the aging process and the plasma lipid parameters tends to change with age and be associated with exceptional human longevity [48]. However, this study found that a larger relative grip strength might not be able to offset the negative effects of obesity, overweight and physical inactivity on hyperlipidemia. This finding is corresponded with those of many previous studies. There has been strong correlation among hypertension, obesity, hyperlipidemia, and hyperuricemia which are important risk factors for CVD. A cross-sectional study published in 2009 demonstrated that hypercholesterolemia, hypertriglyceridemia, and hyperuricemia were not associated with the age of the hypertensive patients, but the Increased BMI was more frequent in the young as compared to the old hypertensive patients [49]. And another survey conducted in 2008 showed that obesity would significantly exacerbate the deleterious association between diabetes, hyperlipidemia, and hypertension, and health function, health perception, and preference [50]. Moreover, a cross-sectional survey conducted in 2002 concluded that there was a significant relationship between the BMI and CVD risk factors and this association could be extended to lower BMI levels[51]..

Lastly, the probability of getting hypercholesterolemia varies less with age and relative grip strength, indicating that relative grip strength might not be a main influence factor of hypercholesterolemia. The plasma cholesterol has been regarded as a CVD risk factor for many years, however, the cause of hypercholesterolemia might not be explained by one or two simple physiological mechanism. A secondary analysis of national-wide cross-sectional survey, which conducted in 2006, claimed that although diagnosis and treatment of hypercholesterolemia had been well established, according to earlier analyses of representative health questionnaire and examination survey, control of CVD risk factors in the sense of normalized values through preventing hypercholesterolemia had not improved to any relevant degree[52]. It is possible that the plasma cholesterol might be mostly related to the endogenous cholesterol metabolism [53]. Further study should analysis the probability of other CVD risk factors related to cholesterol such as HDL-C and LDL-C [54].

## 5. Limitation

There are some limitations of this study. Firstly, the small number of participants over 60 years old might affect the prior distribution of the probability of CVD risk factors in the population above 60 years old. Secondly, there are many measurement approaches to assess individual's muscle strength, the movement of grip strength test only recruits muscles in upper body, the effect on cardiovascular system of which might be smaller than large muscle groups in lower body. Thirdly, although the variation trend of some CVD risk factors showed an upward trend with relative grip strength, few participants had a relative grip strength above 3 in this study. Last but not the least, the blood sample was collected only one time in this study, and the influence of other factors on blood parameters was not considered.

## 6. Conclusion and Recommendations

According to the results of this study and existing clinical evidence, body weight management and keeping high levels of physical activity are recommended at any age. At the same time, although more high-level of evidence is needed, it might benefit to increase some bodyweight after 60 years old to ensure the body have adequate lean body mass and body resources.

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