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ORIGINAL ARTICLE

# Metabolic syndrome predicts incident disability and functional decline among Chinese older adults: results from the China Health and Retirement Longitudinal Study

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## Abstract

**Aims** To investigate the longitudinal association of metabolic syndrome (MetS) and its components with disability outcomes.

**Methods** A total of 5875 participants aged 60 and above completed the 2011 and 2015 waves of the China Health and Retirement Longitudinal Study (CHARLS). MetS at baseline was measured by the National Cholesterol Education Program Adult Treatment Panel III criteria. Logistic regressions were conducted to analyze the associations between baseline MetS and incident disability, measured as the onset of limitations regarding instrumental activities of daily living (IADL) and activities of daily living (ADL) 4 years later. Linear regression was adopted to analyze the longitudinal impact of baseline MetS on the number of IADL and ADL limitations in 2015. A comprehensive list of baseline covariates was adjusted in all regression analyses.

**Results** Baseline MetS was related to increased odds of incident IADL disability (OR = 1.28, 95% CI 1.05–1.55) and incident ADL disability (OR = 1.27, 95% CI 1.05–1.53) among disability-free participants at baseline. Baseline MetS was also associated with an increase in the number of IADL (beta = 0.15, 95% CI 0.07–0.23) and ADL limitations (beta = 0.10, 95% CI 0.01–0.18), while adjusting for baseline functional performance. Significant MetS component predictors of disability outcomes include abdominal obesity, high blood pressure, and a low level of high-density lipoprotein cholesterol.

**Conclusions** Our findings suggest an increased risk of incident disability and deteriorated functional performance over 4 years, associated with the presence of MetS and its components.

**Keywords** Functional decline · Incident disability · Metabolic syndrome · Older adults

## Introduction

Metabolic syndrome (MetS), a constellation of metabolic risk factors, is becoming increasingly common with lifestyle changes, especially among older people [1]. In light of the epidemiological transition to environments dominated by chronic disease and increasing multimorbidity, MetS is particularly important to study, as it consists of a cluster of metabolic abnormalities instead of a single condition, which is a possible marker of future chronic disorders [2].

According to the National Cholesterol Education Program Adult Treatment Panel (NCEP ATP) III [1], MetS can be defined as the simultaneous existence of three or more of the following components: abdominal obesity, high serum triglycerides (TG), a low level of high-density lipoprotein cholesterol (HDL-C), high blood pressure (BP), and raised fasting blood glucose (FBG). The presence of MetS had been implicated in the increased risk of several adverse health

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outcomes, including recurrent stroke [3], cognitive impairment [4], incident disability [2, 5–8], functional decline [9, 10], and mortality [11]. Among these health outcomes, disability is a considerable public health concern because of the socioeconomic caregiving burden. The burden is even more challenging in less affluent countries, where lifestyle transformations that encourage decreased physical activity and increased intake of energy have led to more people developing MetS [12]. The increasing prevalence of MetS in these countries may cause higher rates of disability among older adults, thus burdening society.

Although previous literature has documented a positive longitudinal association between MetS and incident disabilities [2, 5–8] as well as functional decline [9, 10], there is still a lack of evidence in China. To the best of our knowledge, only Yang et al. have examined the association between MetS and disability among the oldest old (90 years and above), which they did in Dujiangyan City (a southwestern city in Sichuan Province of China) and found a positive association between MetS and both ADL and IADL disabilities with cross-sectional data [13]. To improve the power of causal inference and future prediction, further investigation using a longitudinal study design is needed.

Moreover, given the nation's large and fast-growing older population (aged 60 and older) of about 250 million (17.9% of China's population) in 2018 [14] as well as the high prevalence of MetS (33.9%) among Chinese adults according to the 2010 China Noncommunicable Disease Survey [15], it is important to examine this association between MetS and disability outcomes among older populations in China, based on a nationally representative dataset, to help China confront the burden inflicted by the high prevalence of MetS and its associated adverse outcomes.

Using the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative panel study in China, we studied the association between MetS and disability outcomes, including incident disability among disability-free older adults at baseline and functional decline, that were conditional on baseline functional performance.

## Methods

### Study design and participants

Data came from CHARLS, a nationally representative longitudinal study of the middle-aged and elderly population (aged 45 and above) in China. CHARLS, harmonized with the Health and Retirement Study, collects multidisciplinary information, including sociodemographic characteristics and health conditions. The national representativeness of CHARLS derives from strict adherence to stratified probability proportional to size (PPS) random sampling principles. Strict quality control measures ensured that the baseline sample closely matched the 2010 census in demographics [16]. CHARLS included 17,708 respondents at the baseline survey, and these participants were followed up every 2 years afterward by a computer-assisted personal interview (CAPI) administered by trained interviewers (for more details, see Zhao et al.[16]). We used the 2011 and 2015 waves of CHARLS to examine the effects of baseline MetS on incident disability and functional decline over 4 years.

To fulfill our purpose, we included an initial sample of 5875 participants (60 and above in 2011) who had completed the follow-up survey in 2015. We focused on those aged 60 and above because the age of 60 is widely considered as the onset of old age among Chinese people, and the retirement age in China is 50/55 for females and 60 for males. Among the 5875 participants included at baseline, 1871 had missing data for MetS assessment, and 207 had missing values on selected covariates at baseline. For the descriptive analyses, these participants were excluded ($n = 3797$). To examine the association with incident disability, we further restricted our study sample to those who were disability-free in 2011 and had complete information on baseline MetS and disability assessment in 2015, resulting in a final study sample of 2729 and 2890 respondents for incident IADL and ADL, respectively. To study the association between baseline MetS and functional decline, participants with valid values on dependent, independent, and control variables were included. This led to a final sample of 3679 and 3745 participants for the analyses of the IADL and ADL performance, respectively. The process of sample selection is shown in Supplementary Fig. 1.

### Measurement

Metabolic syndrome was identified as the coexistence of three or more of the following: abdominal obesity, high TG, low HDL-C, high BP, and raised FBG according to the updated NCEP ATP III in 2004 [17]. Following recommendations from a previous study [18], abdominal obesity for Chinese adults was defined as a waist circumference exceeding 90 cm for males and 80 cm for females. To retain the maximum number of cases and be consistent with the previous literature [2], we identified high TG, low HDL-C, high BP, and elevated FBG by a hybrid measurement of biomarkers (or objective assessment) and self-reports. Therefore, in this study, high TG was defined as having a serum TG level of 150 mg/dL or higher, or a self-reported doctors' diagnosis of dyslipidemia. Low HDL-C was defined as having an HDL-C of less than 50 mg/dL and 40 mg/dL for women and men, respectively, or self-reported dyslipidemia. CHARLS respondents' blood pressure was measured three times at 45-s intervals [16]. High BP was ascertained by a mean systolic pressure of 130 mmHg or higher, a mean diastolic pressure of 85 mmHg or higher, or self-reported hypertension. Elevated FBG was identified by a fasting plasma glucose level greater than or equal to 100 mg/dL, or a self-reported doctor's diagnosis of diabetes. The protocols for physical measurements and blood collection have been described elsewhere [16, 19].

The outcomes of interest were measures of physical function grouped in two domains: IADL tasks (i.e., cooking, doing household chores, taking medicine, shopping, and managing money) and ADL tasks (i.e., eating, dressing, getting into or out of bed, toileting, bathing, and urinating). For each domain, respondents were considered disabled if they reported that they were unable to complete one or more of the tasks. Incident disability was defined as the onset of at least one limitation by 2015 among individuals free of disability at baseline. The numbers of limitations with ADL and IADL were also calculated as measures of functional performance.

Basic sociodemographic characteristics included age, gender, marital status (married vs. unmarried), residence (rural vs. urban), education level (did not complete primary education vs. primary education or above), medical insurance, and per capita expenditure (PCE). Another important confounder was the individuals' baseline morbidity. Therefore, self-reported diagnoses of chronic lung disease, heart problems, stroke, cancer, arthritis, and memory-related diseases were included, together with depression measured by the Centre for Epidemiologic Studies-Depression scale (CES-D) [20]. Participants with a CES-D score of 10 points or higher were classified as being at a high risk of depression [20]. Health behaviors included smoking (never, past, and current), drinking (never, past, and current), and regular physical exercise.

### Statistical analysis

Univariate analysis was conducted to describe baseline characteristics. A chi-squared test and a *t* test were used to compare participants' characteristics from their baseline MetS status (i.e., no MetS versus MetS).

Three multivariate logistic regressions were conducted to determine the effect of baseline MetS on the onset of IADL disability and ADL disability over 4 years. In Model 1, demographic characteristics, including age, gender, and marital status, were adjusted. In Model 2, socioeconomic characteristics, including urban residence, education, medical insurance, and the log of PCE in 2011, were adjusted. In the fully adjusted Model 3, baseline morbidity and health behaviors were adjusted based on Model 2. Odds ratios (OR) generated by the logistic regression models were reported, along with the 95% confidence intervals (CI). Concerning the analysis of baseline MetS effects on the number of functional limitations at the time of follow-up, multivariate linear regression models were applied while adjusting for the same set of covariates at each stage, except for baseline functional performance, which was controlled at all times. Coefficients and the 95% CIs of MetS estimated by the linear regression models were reported.

We conducted supplementary analyses to evaluate whether each component of MetS was related to incident disability and functional decline. A total of five MetS components were included in the fully adjusted model simultaneously. Stata 15 was employed for data analyses.

## Results

Table 1 reports the participants' characteristics. Among the 3797 participants, the average age was 67.3 years old with a median of 66, 75th percentile of 71, and 90th percentile of 76 years, approximately half (50.4%) were female, and the majority (80.3%) were married. Regarding their socioeconomic characteristics, 34.8% lived in an urban area, and more than half (56.2%) did not attend primary school. A total of 94.6% had at least one type of medical insurance. The PCE, which was used to reflect the participants' economic status, was 8556.6 yuan on average, roughly equivalent to 1324.8 US dollars. The log-transformation variable was used in the regression model. We also included BMI in describing the characteristics of the sample. Among all participants, 8.6% were classified as underweight, 26.0% were classified as overweight, and 59.1% had normal BMI. Characteristics of participants included in our descriptive sample did not differ much from those excluded due to incomplete MetS measurement and missing covariates. Among all the participants included in the descriptive analyses, the rate of MetS was 49.38% ($n = 1875$). Individuals with MetS at baseline were more likely to be female, unmarried, residing in rural areas, and overweight than those without MetS ($p < 0.005$). MetS was also related to a higher probability of cardiovascular diseases, including heart problems ($p < 0.001$) and stroke ($p < 0.001$). For individuals at baseline, the presence of MetS was related to ADL/IADL disability ($p < 0.05$) and more functional limitations ($p < 0.05$). (For more details, see Table 1.)

The association of baseline MetS with newly developed disabilities 4 years later among the disability-free respondents is shown in Table 2. Overall, the proportion of older adults who developed IADL or ADL disability was higher among those with MetS at baseline (28.7% vs. 25.0% for IADL disability, and 27.2% vs. 22.6% for ADL disability).

According to the logistic regression model results, shown in Table 2, when only adjusting for demographics (Model 1), older adults with MetS in 2011 showed a higher probability of newly onset IADL and ADL limitations, but

**Table 1** Characteristics of participants

| Characteristics | Description | All ($n = 3797$) $N$ (%) | No MetS ($n = 1922$) $N$ (%) | MetS ($n = 1875$) $N$ (%) | $p$ Value |
|---|---|---|---|---|---|
| Age, mean (SD) | | 67.3 (6.1) | 67.5 (6.1) | 67.1 (6.0) | 0.071 |
| Gender | Male | 1882 (49.6) | 1203 (62.6) | 679 (36.2) | 0.000 |
| | Female | 1915 (50.4) | 719 (37.4) | 1196 (63.8) | |
| Marital status | Unmarried | 749 (19.7) | 345 (18.0) | 404 (21.5) | 0.005 |
| | Married | 3048 (80.3) | 1577 (82.0) | 1471 (78.5) | |
| Residence | Rural | 2475 (65.2) | 1405 (73.1) | 1070 (57.1) | 0.000 |
| | Urban | 1322 (34.8) | 517 (26.9) | 805 (42.9) | |
| At least primary education | No | 2135 (56.2) | 1079 (56.1) | 1056 (56.3) | 0.911 |
| | Yes | 1662 (43.8) | 843 (43.9) | 819 (43.7) | |
| Log of PCE, mean (SD) | | 8.7 (0.8) | 8.6 (0.8) | 8.8 (0.9) | 0.000 |
| Medical insurance (MI) | No | 205 (5.4) | 103 (5.4) | 102 (5.4) | 0.912 |
| | Yes | 3592 (94.6) | 1819 (94.6) | 1773 (94.6) | |
| BMI | Underweight | 327 (8.6) | 280 (14.6) | 47 (2.5) | 0.000 |
| | Normal | 2244 (59.1) | 1360 (70.9) | 884 (47.0) | |
| | Overweight | 988 (26.0) | 182 (9.5) | 806 (42.9) | |
| | Missing | 238 (6.3) | 95 (5.0) | 143 (7.6) | |
| Chronic lung disease | No | 3218 (84.8) | 1591 (82.8) | 1627 (86.8) | 0.001 |
| | Yes | 579 (15.2) | 331 (17.2) | 248 (13.2) | |
| Heart problems | No | 3155 (83.1) | 1692 (88.0) | 1463 (78.0) | 0.000 |
| | Yes | 642 (16.9) | 230 (12.0) | 412 (22.0) | |
| Stroke | No | 3678 (96.9) | 1890 (98.3) | 1788 (95.4) | 0.000 |
| | Yes | 119 (3.1) | 32 (1.7) | 87 (4.6) | |
| Cancer | No | 3767 (99.2) | 1907 (99.2) | 1860 (99.2) | 0.946 |
| | Yes | 30 (0.8) | 15 (0.8) | 15 (0.8) | |
| Arthritis | No | 2287 (60.2) | 1162 (60.5) | 1125 (60.0) | 0.773 |
| | Yes | 1510 (39.8) | 760 (39.5) | 750 (40.0) | |
| Memory-related disease | No | 3720 (98.0) | 1887 (98.2) | 1833 (97.8) | 0.360 |
| | Yes | 77 (2.0) | 35 (1.8) | 42 (2.2) | |
| CES-D score ≥ 10 | No | 2207 (58.1) | 1117 (58.1) | 1090 (58.1) | 0.992 |
| | Yes | 1590 (41.9) | 805 (41.9) | 785 (41.9) | |
| Smoke | Never | 2225 (58.6) | 953 (49.6) | 1272 (67.8) | 0.000 |
| | Past | 423 (11.1) | 216 (11.2) | 207 (11.0) | |
| | Current | 1149 (30.3) | 753 (39.2) | 396 (21.1) | |
| Drink | Never | 2224 (58.6) | 1002 (52.1) | 1222 (65.2) | 0.000 |
| | Past | 433 (11.4) | 220 (11.4) | 213 (11.4) | |
| | Current | 1140 (30.0) | 700 (36.4) | 440 (23.5) | |
| Physical activity | No | 3569 (94.0) | 1851 (96.3) | 1718 (91.6) | 0.000 |
| | Yes | 228 (6.0) | 71 (3.7) | 157 (8.4) | |
| MetS components in 2011 | | | | | |
| Abdominal obesity | No | 1795 (50.0) | 1460 (79.4) | 335 (19.1) | 0.000 |
| | Yes | 1796 (50.0) | 379 (20.6) | 1417 (80.9) | |
| High TG | No | 2449 (65.4) | 1825 (95.3) | 624 (34.1) | 0.000 |
| | Yes | 1296 (34.6) | 90 (4.7) | 1206 (65.9) | |
| Low HDL cholesterol | No | 2107 (56.0) | 1709 (89.2) | 398 (21.6) | 0.000 |
| | Yes | 1653 (44.0) | 207 (10.8) | 1446 (78.4) | |
| High BP | No | 1263 (34.1) | 999 (53.8) | 264 (14.3) | 0.000 |
| | Yes | 2440 (65.9) | 859 (46.2) | 1581 (85.7) | |
| Elevated FBG | No | 1330 (38.5) | 1031 (58.0) | 299 (17.9) | 0.000 |
| | Yes | 2123 (61.5) | 747 (42.0) | 1376 (82.1) | |

**Table 1** (continued)

| Characteristics | Description | All ($n=3797$) $N$ (%) | No MetS ($n=1922$) $N$ (%) | MetS ($n=1875$) $N$ (%) | $p$ Value |
|---|---|---|---|---|---|
| Functional performance in 2011 | | | | | |
| Any IADL difficulty | No | 2763 (73.0) | 1443 (75.4) | 1320 (70.6) | 0.001 |
| | Yes | 1021 (27.0) | 472 (24.6) | 549 (29.4) | |
| Number of IADL, mean (SD) | | 0.6 (1.1) | 0.5 (1.1) | 0.6 (1.2) | 0.003 |
| Any ADL difficulty | No | 2899 (76.9) | 1500 (78.6) | 1399 (75.1) | 0.012 |
| | Yes | 872 (23.1) | 409 (21.4) | 463 (24.9) | |
| Number of ADL, mean (SD) | | 0.5 (1.1) | 0.4 (1.0) | 0.5 (1.1) | 0.039 |
| Functional performance in 2015 | | | | | |
| Any IADL difficulty | No | 2440 (65.2) | 1287 (68.0) | 1153 (62.2) | 0.000 |
| | Yes | 1305 (34.8) | 605 (32.0) | 700 (37.8) | |
| Number of IADL, mean (SD) | | 0.8 (1.3) | 0.7 (1.3) | 0.9 (1.4) | 0.000 |
| Any ADL difficulty | No | 2556 (67.5) | 1348 (70.4) | 1208 (64.6) | 0.000 |
| | Yes | 1229 (32.5) | 566 (29.6) | 663 (35.4) | |
| Number of ADL, mean (SD) | | 0.7 (1.3) | 0.7 (1.3) | 0.8 (1.4) | 0.002 |

**Table 2** Logistic analysis of the association between baseline MetS and incident disability

| Independent variables | No. | Incidence no. (%) | Model 1[a] | | Model 2[b] | | Model 3[c] | |
|---|---|---|---|---|---|---|---|---|
| | | | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Incident IADL disability ($N=2729$) | | | | | | | | |
| Baseline MetS | | | | | | | | |
| No | 1423 | 356 (25.0) | Ref | | Ref | | Ref | |
| Yes | 1306 | 375 (28.7) | 1.09 | [0.92,1.31] | 1.27* | [1.06,1.53] | 1.28* | [1.05,1.55] |
| Incident ADL disability ($N=2890$) | | | | | | | | |
| Baseline MetS | | | | | | | | |
| No | 1494 | 337 (22.6) | Ref | | Ref | | Ref | |
| Yes | 1396 | 379 (27.2) | 1.18 | [0.98,1.41] | 1.27* | [1.06,1.52] | 1.27* | [1.05,1.53] |

[a]Age, gender, and marital status were adjusted

[b]Urban residence, education, medical insurance, and log of PCE in 2011 were further adjusted

[c]Based on Model 2, self-report diagnosis of chronic lung disease, heart problems, stroke, cancer, arthritis, and memory-related disease, depression, and behaviors including smoking, drinking, and physical activity in 2011 were additionally adjusted

*$p<0.05$

**$p<0.01$

***$p<0.001$

the results were not statistically significant. Further adjustment for socioeconomic factors strengthened the association. As shown in Model 2, baseline MetS was associated with a 1.27-times probability of incident IADL disability (OR = 1.09, 95% CI 1.06–1.53, $p<0.05$), and a 1.27-times probability of incident ADL disability (OR = 1.18, 95% CI 1.06–1.52, $p<0.05$). The controls for chronic diseases, depressive symptoms, and health behaviors further revealed an increased odds ratio among participants with MetS for incident IADL disability (OR = 1.28, 95% CI 1.05–1.55, $p<0.05$) and for incident ADL disability (OR = 1.27, 95% CI 1.05–1.53, $p<0.05$).

Table 3 shows results from the multivariate linear regression analyses of the number of functional limitations in 2015 while adjusting for baseline functional performance. The results show that participants with MetS at baseline had more IADL (0.9 vs. 0.7) and ADL limitations (0.8 vs. 0.7) in 2015.

As the regression analysis indicated, the presence of MetS remained a consistently significant and independent risk factor of functional decline over 4 years. After adjusting for demographic characteristics, socioeconomic characteristics, and baseline functional performance (Model 2), the presence of MetS was linked to a significantly increased number of

**Table 3** Linear regression of the association between baseline MetS and limitations in 2015

| Independent variables | No. | Mean (SD) | Model 1[a] | | Model 2[b] | | Model 3[c] | |
|---|---|---|---|---|---|---|---|---|
| | | | Beta | 95% CI | Beta | 95% CI | Beta | 95% CI |
| Number of IADL limitations ($N=3679$) | | | | | | | | |
| Baseline MetS | | | | | | | | |
| No | 1854 | 0.7 (1.3) | Ref | | Ref | | Ref | |
| Yes | 1825 | 0.9 (1.4) | 0.12** | [0.04,0.20] | 0.16*** | [0.08,0.24] | 0.15*** | [0.07,0.23] |
| Number of ADL limitations ($N=3745$) | | | | | | | | |
| Baseline MetS | | | | | | | | |
| No | 1893 | 0.7 (1.3) | Ref | | Ref | | Ref | |
| Yes | 1852 | 0.8 (1.4) | 0.08 | [−0.01,0.16] | 0.11** | [0.03,0.20] | 0.10* | [0.01,0.18] |

[a]Age, gender, marital status, and functional performance in 2011 were adjusted

[b]Urban residence, education, medical insurance, and log of PCE in 2011 were further adjusted

[c]Based on Model 2, self-report diagnosis of chronic lung disease, heart problems, stroke, cancer, arthritis, and memory-related disease, depression, and behaviors including smoking, drinking, and physical activity in 2011 were additionally adjusted

*$p<0.05$

**$p<0.01$

***$p<0.001$

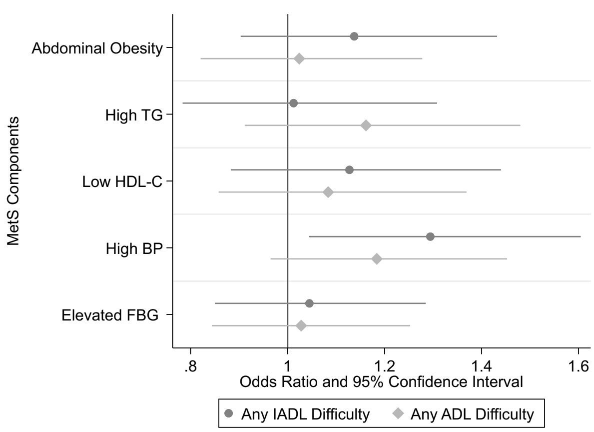


**Fig. 1** OR and 95% CI of incident disability by metabolic syndrome component. Adjusted for age, gender, marital status, urban residence, education, medical insurance, the log of PCE, self-report diagnosis of chronic lung disease, heart problems, stroke, cancer, arthritis, memory-related disease, depression, smoking, drinking, and physical activity

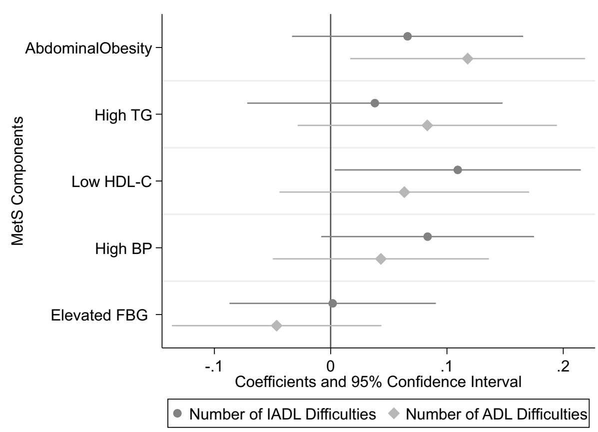


**Fig. 2** Coefficient and 95% CI of functional performance by metabolic syndrome component. Adjusted for functional performance in 2011, and baseline characteristics including age, gender, marital status, urban residence, education, medical insurance, the log of PCE, self-report diagnosis of chronic lung disease, heart problems, stroke, cancer, arthritis, and memory-related disease, depression, smoking, drinking, and physical activity

IADL ($p<0.001$) and ADL limitations ($p<0.01$). Although further adjustment of baseline morbidity and health behaviors in Model 3 slightly attenuated these associations, the presence of MetS remained statistically significant (IADL: beta = 0.15, $p<0.001$; ADL: beta = 0.10, $p<0.05$).

We evaluated whether each MetS component was associated with the incident IADL/ADL disability and the number of limitations. Figure 1 illustrates the OR and 95% CI of each MetS component obtained from multivariate logistic analyses of incident ADL/IADL limitations, conditional on all other covariates. Figure 1 shows that high BP and low HDL-C were associated with both disability outcomes, with a larger magnitude seen for high BP. Abdominal obesity was only associated with incident IADL disability, whereas high TG was only associated with incident ADL disability. Figure 2 shows the association of each MetS component with the decline in ADL/IADL performance. The linear regression model shows that all five components, except for elevated FBG, were associated with functional decline in both ADL and IADL. Low HDL-C and high BP were the strongest predictors of an increase in the number of IADL limitations. Regarding the number of ADL limitations, abdominal obesity exhibited the largest magnitude of effects.

To summarize, the consistent and significant predictors of incident limitations and deterioration in functional performance were abdominal obesity, high BP, and low HDL-C.

## Discussion

The present research is the first to highlight the longitudinal association between MetS and disability outcomes based on a nationally representative and longitudinal cohort of Chinese older people. Our findings suggested that the presence of MetS had strong links with disability outcomes, including newly developed IADL/ADL disability and declining functional performance (indicated by more IADL and ADL limitations), after adjusting for participants' sociodemographics, baseline morbidity, and health behaviors. Among all the MetS components, abdominal obesity, low HDL-C, and high BP were strong predictors of incident limitations and deteriorating functional performance over time.

Our findings regarding the MetS-disability association were consistent with previous longitudinal studies, confirming that baseline MetS was a risk factor for incident disability among disability-free participants at baseline [2, 5–8]. The findings also confirmed an increase in the severity of limitations conditional on functional status at baseline [9, 10]. For instance, using the Three-City data (Bordeaux, Dijon, and Montpellier) in France, Carriere et al. found that MetS, also measured by the NCEP ATP III, was associated with IADL limitation among 6164 participants aged 65 and older [2]. An association between MetS and incident disabilities was also found in research that used a different metabolic status measure, with the clustered groups based on 11 metabolic parameters [6]. MetS was also predictive of functional decline, a result consistent with findings of studies among participants from the Sacramento Area Latino Study on Aging [9] and the Duke Established Populations for Epidemiologic Studies of the Elderly [10]. Our longitudinal study, based on nationally representative data from China, a country with high MetS prevalence in older adults, adds evidence to this body of knowledge. Furthermore, building upon previous research [2, 5, 6, 10, 21, 22], this study included a comprehensive list of covariates.

The effects of MetS on the incident of disability and functional decline are biologically plausible and may operate through several underlying mechanisms, including dyslipidemia, insulin resistance, glucose intolerance, hypertension, and other manifestations [1]. These mechanisms are associated with the inflammation process [23], influencing muscles [24], cardiovascular events [3], osteoarthritis [25], and frailty level [26], which are risk factors of disability and functional limitation [27–29].

Our findings regarding associations between specific MetS components and functional limitations are consistent with those of previous literature showing that abdominal obesity [2, 5], high BP [2, 5], and low HDL-C [30] are significantly associated with incident ADL/IADL limitations or deteriorated ADL/IADL performance. In contrast to previous studies among Americans [5], we found insignificant and negligible effects of elevated FBG among Chinese residents, which is highly consistent with previous cross-country analyses of the difference in the diabetes-disability association among adults aged 40 and older. This insignificant association might also be caused by the adjustment for variables, including physical activity, which may explain the links between diabetes and ADL [31].

Our study has several limitations. First, we just measured MetS at baseline, leaving open the possibility that trajectories in MetS status may exist during the study window. Second, participants' functional performance and morbidity come from self-reports, which may suffer from record bias. Third, there is a possible over-adjustment. For example, using physical activity as a control variable may reduce the influence of MetS components. Also, due to mortality selection, participants who completed the baseline and follow-up surveys tend to be younger or have a better health condition at baseline.

In conclusion, using nationally representative data, this prospective cohort study investigates the association between MetS and incident disabilities as well as functional decline over 4 years. The results established evidence that baseline MetS is an independent predictor of the onset of IADL/ADL disabilities and the deterioration of functional performance among Chinese older adults, adjusting for the participants' sociodemographic characteristics, morbidity status, and health behaviors. Abdominal obesity, high BP, and low HDL-C were significantly related to disability outcomes. Interventional measures targeting specific components of MetS, including weight reduction and physical exercise, are likely to help prevent functional decline among older adults.

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## Declarations

**Conflict of interest** The authors declare no conflict of interest.

**Ethical approval** The protocols of CHARLS were approved by the Ethical Committee at Peking University. All participants in CHARLS gave informed consent.

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