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ORIGINAL ARTICLE

Association among plasma lactate, systemic inflammation, and mild cognitive impairment: a community-based study

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Abstract

The level of lactate in the blood is associated with obesity, blood pressure, and type 2 diabetes. In addition, lactate is a pro-inflammatory cytokine, which plays an important role in the pathogenesis of cognitive impairment. However, the association between blood lactate, systemic inflammation, and mild cognitive impairment (MCI) has not been investigated. The aim of the study is to explore this association in a Chinese population. This community-based cross-sectional study included 2523 Chinese participants aged 18–88 years. Cognitive function was assessed using the Chinese version of the Mini-Mental State Examination. MCI was defined using education-based cutoffs. The concentration of plasma lactate and serum high-sensitivity C-reactive protein (hs-CRP) was measured using the lactate oxidase method and latex enhanced immunoturbidimetric assay, respectively. Compared with participants without a cognitive impairment, participants with a MCI had an increased concentration of plasma lactate and serum hs-CRP ($P < 0.001$). As blood lactate increased, the concentration of serum hs-CRP and prevalence of MCI also increased ($P < 0.001$). Logistic regression analysis showed that plasma lactate (odds ratio (OR) 2.76, 95% confidence interval (CI) 2.21–3.45, $P < 0.001$) and serum hs-CRP (OR 1.15, 95% CI 1.08–1.24, $P < 0.001$) were significant risk factors for MCI. The adjusted OR for MCI in participants in the fourth lactate quartile was 3.44 (95% CI 2.02–5.88, $P < 0.001$) compared with the first quartile. Our results showed that plasma lactate is associated with systemic inflammation and MCI.

Keywords Plasma lactate · Systemic inflammation · Mild cognitive impairment · Epidemiology

Introduction

Cognition is an important manifestation of higher nervous system activity in the cerebral cortex [1]. Mild cognitive impairment (MCI) is a clinical condition characterized by reduction in memory and/or other cognitive processes not severe enough to meet the criteria for dementia [2]. Individuals with MCI can progress to Alzheimer's disease (AD), which is the main cause of dementia in the elderly population [2, 3]. It has been estimated that the annual conversion rate of MCI patients to AD is 10–15% [4]. Cognitive function decline with aging has been reported widely [5]. In addition, other factors, such as obesity, hypertension, dyslipidemia, and diabetes, are associated with cognitive function decline [6–8].

Lactate is produced from pyruvate by the enzymatic action of lactate dehydrogenase. Lactate can be used as an alternative fuel for brain metabolism during hypoglycemia [9]. Conversely, blood lactate at rest is a marker of mitochondrial dysfunction; a reduction in mitochondrial function induces an increase in blood lactate due to increased flux via glycolytic pathways [10]. Furthermore, mitochondrial dysfunction is an important early factor in accelerated cognitive decline and AD [11]. Lactate expression in the precuneus/posterior cingulate, measured using magnetic resonance spectroscopy, is increased in individuals with amnestic MCI with greater disease progression. In addition, elevated lactate levels in the cerebrospinal fluid are associated with cognitive impairment in patients with AD [12, 13]. Furthermore, lactate has been shown to activate, or boost the production of, pro-inflammatory cytokines, which play an important role in the pathogenesis of cognitive impairment [14–18].

Hua Pan and Xiuji Huang contributed equally to this work.

Study population Participants were recruited from the urban and rural community in Guangzhou, Guangdong, China. The study population was drawn from the Thyroid disorders, iodine status, and diabetes: a national epidemiological survey-2014 study in China.

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Previous studies have reported that the concentration of blood lactate is associated with obesity, blood pressure, type 2 diabetes, heart failure, and other causes of mortality [10, 19, 20]. However, the association between the concentration of blood lactate and cognitive function has not been investigated. Thus, we conducted this study to explore the relationship between plasma lactate, systemic inflammation, and MCI in a community-based Chinese population.

Methods

Study population

This cross-sectional study was conducted from March 2015 to June 2015. A total of 2698 inhabitants, aged ≥ 18 years, participated in the study, including 1402 and 1296 inhabitants residing in urban and rural areas, respectively. Participants with clinical dementia (based on the Diagnostic and Statistical Manual of Mental Disorders, fourth edition criteria, $n = 3$); a previous diagnosis of stroke ($n = 15$); an inability to communicate with the interviewer ($n = 5$); a prescription of metformin or pioglitazone ($n = 51$), which might increase or decrease plasma lactate level [20, 21]; plasma lactate ≥ 5 mmol/L ($n = 1$), which indicates systemic hypoperfusion [10]; high-sensitive C reactive protein (hs-CRP) ≥ 10 mg/L ($n = 26$), which indicates acute inflammations [22]; missing lactate values ($n = 36$); or hs-CR*P* values ($n = 38$) were excluded from the study. Therefore, 2523 participants were included in the analysis.

Anthropometry and blood pressure measurements

We measured height and weight, and calculated body mass index (BMI) as weight (kg) divided by the square of the height (m). Blood pressure was measured twice, while seated and after at least a 10-min rest, using an automated monitor (HEM-8102A, Omron Healthcare, Co., Ltd., Tokyo, Japan), with subsequent estimation of the mean of the two measurements. Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or antihypertensive medication use.

Smoking, alcohol drinking, education, and physical activity information

Information about smoking (yes or no), drinking (yes or no), and education (< 6, 6–12, and > 12 years of education) was collected via interviews and questionnaires. The level of physical activity was determined using questions relating to spent doing physical activity during leisure time in the previous week time (lower < 0.5, middle 0.5–1, higher > 1 h per day, respectively).

Measurement of cognitive function

For the assessment of global cognitive function, trained doctors applied a validated Chinese version of the Mini Mental State Examination (MMSE). This test was performed face-to-face in a quiet space. The investigator explained the purpose and value of the investigation prior to commencing with questions. The MMSE consists of 11 items, including 30 questions related to orientation to time and place, immediate recall, short-term verbal memory, calculation, language, and construct ability. The score ranges from 1 to 30. Validated, education-based cutoff points were used to define MCI: 19/20 for illiteracy, 22/23 for 1–6 years of education, and 26/27 for ≥ 6 years of education [23].

Blood sample collection

After an overnight 8–10-h fast, blood samples were collected to detect lactate, fasting plasma glucose (FPG), total cholesterol (TC), triglyceride (TG), low-density lipoprotein–cholesterol (LDL-C), high-density lipoprotein–cholesterol (HDL-C), and high-sensitivity C-reactive protein (hs-CRP). After fasting blood samples were collected, a 75-g oral glucose tolerance test (OGTT) was performed, and blood samples were collected 2 h post-glucose loading, for the detection of glucose.

Blood biochemical marker measurements

Plasma lactate was measured using the lactate oxidase method (Co-Health [Beijing] Laboratories Co., Ltd., Beijing, China); the inter- and intra-assay coefficients of variability (CV) were 1.9% and 1.6%, respectively. Blood glucose was measured using the hexokinase method (Co-Health [Beijing] Laboratories Co., Ltd.); the inter- and intra-assay CVs were 2.9% and 1.1%, respectively. TC was measured using the cholesterol oxidase-peroxidase method (Co-Health [Beijing] Laboratories Co., Ltd.); the inter- and intra-assay CVs were 3.8% and 1.2%, respectively. TG was measured using the glycerol phosphate oxidase-p-aminophenazone method (Co-Health [Beijing] Laboratories Co., Ltd.); the inter- and intra-assay CVs were 3.0% and 1.6%, respectively. LDL-C was measured using a surfactant elimination method (Co-Health [Beijing] Laboratories Co., Ltd), and the inter- and intra-assay CVs were 4.5% and 2.9%, respectively. HDL-C was measured by polyanion polymer/detergent method (Co-Health [Beijing] Laboratories Co., Ltd.), and the inter- and intra-assay CVs were 5.2% and 2.4%, respectively. hs-CRP was measured using the latex enhanced immunoturbidimetric assay (Ningbo Medical System Biotechnology Co., Ltd., Zhejiang, China); the inter- and intra-assay CVs were 6.8% and 5.2%, respectively. These blood biochemical markers were determined using an ADVIA 1200 Automatic Biochemistry Analyzer.

Based on 1999 World Health Organization diagnostic criteria, diabetes is defined as FPG ≥ 7.0 mmol/L, 2-h plasma glucose during OGTT ≥ 11.1 mmol/L, or self-reported physician diagnose of diabetes. Dyslipidemia was defined as level of TC > 5.17 mmol/L, TG > 1.69 mmol/L, LDL-C > 3.37 mmol/L, HDL-C < 1.04 mmol/L, or under medication of lipid-lowering drugs [24].

Statistical analysis

Participant characteristics by cognitive impairment status were compared using analysis of variance (ANOVA) for normally distributed variables, Wilcoxon test for non-normal distributed variables, and chi-squared tests for categorical variables.

The study population was further classified into four groups based on lactate quartile levels (Q1 < 0.986, Q2 0.986–1.255, Q3 1.256–1.613, Q4 > 1.613 mmol/L). Linear regression analysis was used to test for trends across groups. Differences among groups were tested using one-way ANOVA. Comparisons between categorical variables were performed by chi-squared tests.

Logistic regression analysis was used to compare differences in variables between participants with and without MCI. In addition, we analyzed the impact of plasma lactate on hs-CRP using linear regression analysis. Because of the skewed distributions of hs-CRP, we transformed hs-CRP (hs-CRP + 1) values using natural logarithms before regression analysis, as described in previous studies [25]. In addition, we analyzed the effect of plasma lactate level on the prevalence of MCI. Logistic regression analysis was used to assess the prevalent risk of MCI. In the logistic regression analysis, we constructed three models for covariate adjustment. Model 1 was the unadjusted model. Model 2 included age, sex, and BMI. Model 3 incorporated all the variables in Model 2 plus region (urban/rural), level of education, smoking status, alcohol intake, physical activity, diabetes, hypertension, and dyslipidemia. Odds ratios (ORs) and corresponding 95% confidence intervals (95% CI) were calculated.

All statistical analyses were conducted using SPSS (version 18, SPSS Inc., Chicago, IL), and $P < 0.05$ (two-sided) was considered statistically significant.

Results

The mean age of the study population was 46.0 ± 15.3 years, 58.1% were women, and 51.2% lived in urban residences. The prevalence of MCI was 8.2% in the total population. The comparison between participants with and without MCI is shown in Table 1. Compared with participants without MCI, participants with MCI were older, more frequently female, less frequently resident in urban area, and had a lower level of education and prevalence of alcohol drinking, and higher prevalence of diabetes, hypertension, and dyslipidemia, and higher levels of plasma lactate and serum hs-CRP (all $P < 0.01$).

Table 1 Characteristics of study population by cognitive status

Characteristics	MCI		*P* value
	No (*n* = 2315)	Yes (*n* = 208)	
Age (years)	44.57 ± 14.56	61.46 ± 14.81	< 0.001
Female sex [*n* (%)]	1310 (56.6)	155 (74.5)	< 0.001
Urban residence [*n* (%)]	1220 (52.7)	72 (34.6)	< 0.001
Level of education [*n* (%)]			< 0.001
Lower	1132 (48.9)	184 (88.5)	
Middle	460 (19.9)	11 (5.3)	
Higher	723 (31.2)	13 (6.3)	
Smoking [*n* (%)]	465 (20.1)	44 (21.2)	0.713
Drinking [*n* (%)]	1207 (52.1)	40 (19.2)	< 0.001
Level of physical activity [*n* (%)]			< 0.001
Lower	1132 (48.9)	184 (88.5)	
Middle	460 (19.9)	11 (5.3)	
Higher	723 (31.2)	13 (6.3)	
BMI (kg/m^2)	23.51 ± 3.64	23.62 ± 3.59	0.689
Diabetes [*n* (%)]	188 (8.1)	37 (17.8)	< 0.001
Hypertension [*n* (%)]	715 (30.9)	119 (57.2)	< 0.001
Dyslipidemia [*n* (%)]	1339 (57.8)	143 (68.8)	0.002
Lactate (mmol/L)[a]	1.23 (0.97–1.58)	1.48 (1.22–1.95)	< 0.001
hs-CRP (mg/L)[a]	1.03 (1.03–2.14)	1.23 (0.63–3.12)	< 0.001

MCI mild cognitive impairment, BMI body mass index, hs-CRP high-sensitivity C reactive protein

[a] Data are shown as median (interquartile range). Analysis of variance was used for normally distributed variables, Wilcoxon test for non-normal distributed variables, and chi-squared tests for categorical variables

Next, we analyzed the association between plasma lactate and MCI. As shown in Fig. 1, increased plasma lactate was associated with an increase in the probability of MCI. According to the lactate quartile levels, participants with higher plasma lactate levels showed a higher prevalence of MCI (Q1 3.5%, Q2 5.5%, Q3 9.7%, Q4 14.3%; *P* for trend < 0.001; Table 2). Meanwhile, participants with higher plasma lactate levels had also higher levels of Ln (hs-CRP + 1; *P* for trend < 0.001) (Fig. 2).

In addition, we used logistic regression analysis to explore the risk factors of MCI. We found that age (OR 1.08, 95% CI 1.07–1.10, $P < 0.001$), sex (OR 2.24, 95% CI 1.63–3.10, $P < 0.001$), region (OR 2.11, 95% CI 1.56–2.83, $P < 0.001$)), level of education (OR 0.28, 95% CI 0.21–0.37, $P < 0.001$), alcohol drinking (OR 0.22, 95% CI 0.15–0.31, $P < 0.001$), diabetes (OR 2.45, 95% CI 1.67–3.60, $P < 0.001$), hypertension (OR 2.99, 95% CI 2.24–3.99, $P < 0.001$), dyslipidemia (OR 1.60, 95% CI 1.18–2.18, $P = 0.002$), plasma lactate (OR 2.76, 95% CI 2.21–3.45, $P < 0.001$), and serum hs-CRP (OR 1.15, 95% CI 1.08–1.24, $P < 0.001$) were the significant risk factors of MCI (Table 3). Since age is an important influential factor of cognitive

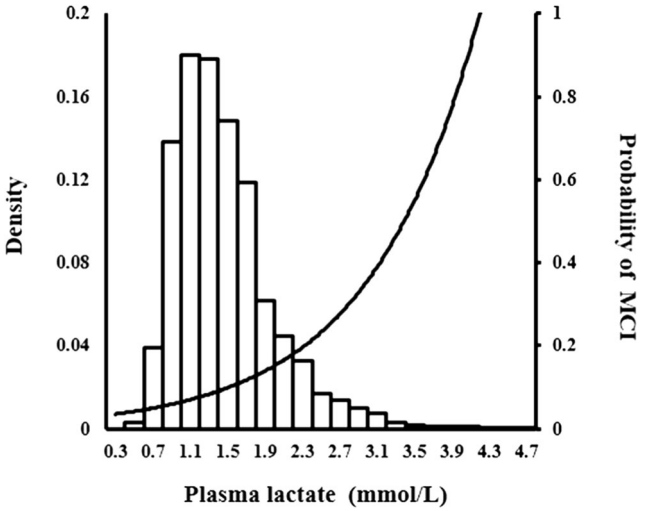

Fig. 1 Probability of mild cognitive impairment and concentration of blood lactate in 2523 Chinese adults. Bars represent the distribution of lactate, and the solid line denotes the predicted probability of MCI (right axis). MCI mild cognitive impairment

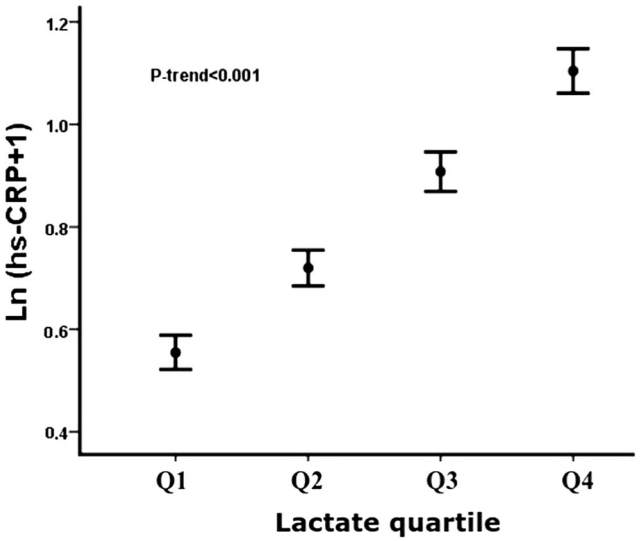

Fig. 2 Association of plasma lactate with hs-CRPs. Mean hs-CRP with 95% confidence intervals by plasma lactate quartile. Plasma lactate quartile was presented as Q1: < 0.986 mmol/L, Q2: 0.986–1.255 mmol/L, Q3: 1.256–1.613 mmol/L, and Q4: > 1.613 mmol/L. *P* for trend was calculated for the linear regression analysis tests across the groups. hs-CRP high-sensitivity C reactive protein

impairment, we divided the study population into three subgroups by age (< 40, 40–60, and > 60 years) to analyze the effect of age on MCI. We found that compared with the < 40-year group, the ORs for MCI in the 40–60-year group and > 60-year group were 3.57 (95% CI 2.21–5.77, $P < 0.001$) and 12.40 (95% CI 7.71–19.95, $P < 0.001$), respectively.

To further explore the association between plasma lactate and MCI, logistic regression analysis was used to assess the prevalent risk of MCI. In Model 1, the fourth quartile of plasma lactate was associated with a 4.61-fold (95% CI 2.85–7.45,

Table 2 Characteristics of study population by plasma lactate quartiles (mmol/L)

Characteristics	Q1, < 0.986 (*n* = 630)	Q2, 0.986–1.255 (*n* = 632)	Q3, 1.256–1.613 (*n* = 631)	Q4, > 1.613 (*n* = 630)	*P* for trend
Age (years)	41.79 ± 14.89	45.70 ± 15.34	47.25 ± 15.05	49.12 ± 15.00	< 0.001
Female sex [*n* (%)]	413 (65.5)	367 (58.1)	356 (56.4)	329 (52.2)	< 0.001
Urban residence [*n* (%)]	349 (55.4)	330 (52.2)	313 (49.6)	300 (47.6)	0.004
Level of education [*n* (%)]					< 0.001
Lower	261 (41.4)	312 (49.4)	344 (54.5)	399 (63.3)	
Middle	131 (20.8)	124 (19.6)	114 (18.1)	102 (16.2)	
Higher	238 (37.8)	196 (31.0)	173 (27.4)	129 (20.5)	
Smoking [*n* (%)]	100 (15.9)	124 (19.6)	128 (20.3)	157 (24.9)	< 0.001
Drinking [*n* (%)]	341(54.1)	311 (49.2)	300 (47.5)	295 (46.8)	0.008
Level of physical activity [*n* (%)]					0.01
Lower	365 (57.9)	355 (56.2)	379 (60.1)	400 (63.5)	
Middle	147 (23.3)	164 (25.9)	160 (25.4)	135 (21.4)	
Higher	118 (18.7)	113 (17.9)	92 (14.6)	95 (15.1)	
BMI (kg/m^2)	22.13 ± 3.20	23.15 ± 3.41	23.89 ± 3.54	24.92 ± 3.80	< 0.001
Diabetes [*n* (%)]	18 (2.9)	38 (6.0)	63 (10.0)	106 (16.8)	< 0.001
Hypertension [*n* (%)]	120 (19.0)	181 (28.6)	216 (34.2)	317 (50.3)	< 0.001
Dyslipidemia [*n* (%)]	261 (41.4)	367 (58.1)	407 (64.5)	447 (71.0)	< 0.001
hs-CRP (mg/L)	0.57 (0.29–1.00)	0.97 (0.48–1.48)	1.24 (0.78–2.27)	1.99 (0.97–3.47)	< 0.001
MCI [*n* (%)]	22 (3.5)	35 (5.5)	61 (9.7)	90 (14.3)	< 0.001

P for trend was calculated for the linear regression analysis tests across the groups

MCI mild cognitive impairment, BMI body mass index, hs-CRP high-sensitivity C reactive protein

Table 3 Risk factor of mild cognitive impairment by logistic regression analysis

Characteristics	*B*	SE	OR	95% CI	*P* value
Age	0.079	0.006	1.08	1.07–1.10	< 0.001
Sex	0.808	0.165	2.24	1.63–3.10	< 0.001
Region	0.744	0.152	2.11	1.56–2.83	< 0.001
Education level[a]	− 1.291	0.147	0.28	0.21–0.37	< 0.001
Smoking	0.065	0.178	1.07	0.75–1.51	0.713
Drinking	− 1.521	0.181	0.22	0.15–0.31	< 0.001
Physical activity[a]	0.028	0.095	1.03	0.85–1.24	0.766
BMI	0.008	0.020	1.01	0.97–1.05	0.689
Diabetes	0.895	0.197	2.45	1.67–3.60	< 0.001
Hypertension	1.096	0.147	2.99	2.24–3.99	< 0.001
Dyslipidemia	0.472	0.155	1.60	1.18–2.18	0.002
Lactate	1.015	0.114	2.76	2.21–3.45	< 0.001
hs-CRP	0.142	0.036	1.15	1.08–1.24	< 0.001

BMI body mass index, hs-CRP high-sensitivity C reactive protein

[a] Processing as classification variables, education (< 6, 6–12, and > 12 years), physical activity (< 0.5 h/day, 0.5–1 h/day, > 1 h/day)

$P < 0.001$) increase in the odds of prevalent MCI when compared with the first quartile. In Model 2, this association was attenuated (OR 3.89, 95% CI 2.32–6.53, $P < 0.001$). In Model 3, the association between the concentration of plasma lactate and MCI was significantly attenuated, and the OR for MCI for participants in the fourth quartile of plasma lactate was 3.44 (95% CI 2.02–5.88, $P < 0.001$) compared with those in the first quartile (Table 4).

Discussion

In the present study, we examined the relationship between the plasma lactate, systemic inflammation, and MCI. We found that the concentration of plasma lactate was associated with systemic inflammation. After adjustments, we found that higher plasma lactate levels were associated with a higher prevalence of MCI in the Chinese population.

During the fasted, resting state, lactate is produced by skeletal muscle, adipose tissue, and the brain [19]. However, lactate in the blood is an indicator of mitochondrial dysfunction [10], and mitochondrial dysfunction plays an important role in the pathogenesis of cognitive impairment [26]. Mitochondria are important organelles that provide > 90% of total ATP supply in neurons [27]. Mutations in mtDNA often result in severe multisystemic disease, while the brain appears most susceptible to mitochondrial defects, suggesting that neurons are particularly sensitive to energy supply by mitochondria [26]. Older monkeys exhibit dysfunctional-shaped mitochondria within presynaptic boutons in the prefrontal cortex, and the number of dysfunctional-shaped mitochondria is correlated with a worsening of working memory [28]. Mitochondrial dysfunction is an early feature of brain function change in AD [29]. Increased blood lactate indicates that the oxidative capability of mitochondrial function has decreased in the body, including the brain. Lactate levels in the cerebrospinal fluid (CSF) and brain were associated with cognitive impairment [12, 13]. In addition, a recent study has shown a direct correlation between CSF and blood lactate levels [30]. Since blood sample is more readily available and less invasive than CSF sample, blood lactate might represent a useful alternative biomarker to CSF lactate for brain mitochondrial function and cognitive function. Thus, based on the above studies and our findings, we supposed that the association between blood lactate and cognitive function might reflect the relationship between mitochondrial dysfunction in the brain and cognitive impairment, and increased blood lactate may be an early marker of cognitive impairment.

In addition to an indirect indicator of mitochondrial dysfunction, lactate has been considered as a potential proinflammatory-signaling molecule [14–18]. Lactate increases production of reactive oxygen species (ROS) and the DNA binding activities of nuclear factor-kappa B (NF-κB) in L6 myogenic cells [14]. Furthermore, lactate activates, or boosts the production of, pro-inflammatory cytokines in macrophages and chondrocytes [15, 16]. Increased lactate production via the anaerobic glycolysis pathway was considered to be the major contributor to the pro-inflammatory trait of

Table 4 Association of plasma lactate levels with incidence of mild cognitive impairment

Quartile of plasma lactate (mmol/L)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Q1 ($n = 630$): < 0.986	1	1	1
Q2 ($n = 632$): 0.986–1.255	1.62 (0.94–2.79)	1.30 (0.73–2.30)	1.23 (0.69–2.19)
Q3 ($n = 631$): 1.256–1.613	2.96 (1.79–4.88)	2.52 (1.48–4.28)	2.37 (1.38–4.06)
Q4 ($n = 630$): > 1.613	4.61 (2.85–7.45)	3.89 (2.32–6.53)	3.44 (2.02–5.88)
P for trend	< 0.001	< 0.001	< 0.001

P for trend was calculated using logistic regression analysis across the groups. Model 1 is the unadjusted model. Model 2 adjusts for age, sex, and body mass index. Model 3 additionally adjusts for region, level of education, smoking status, alcohol drinking, physical activity, diabetes, hypertension, and dyslipidemia

macrophages in the adipose tissue of obese mice [18]. Inflammation also plays an important role in the pathogenesis of cognitive impairment [17]. Serum IL-6, TNF-α, and IL-1β levels are increased significantly in AD patients [31]. Elevated concentrations of CRP and IL-6 are associated with accelerated cognitive decline [32]. Transgenic mice with neuron-specific overexpression of TNF-α exhibit severe inflammation, encephalopathy, and neurodegeneration [17]. In vitro, lactate induced release of TNF-a, IL-1β, and IL-6 from microglia, which are the resident macrophages in the brain [33, 34]. In the present study, we found that an increase in plasma lactate was associated with a higher prevalence of MCI, but also with higher hs-CRP levels, the best characterized and standardized biomarker of systemic inflammation. Thus, we hypothesize that the association between lactate and MCI may be causal, with the pro-inflammatory effect of lactate being an important mechanism in this.

In addition to blood lactate and hs-CRP, we found that age, sex, region (urban/rural), education level, alcohol drinking, diabetes, hypertension, and dyslipidemia were associated with MCI, which is consistent with other studies [23, 35]. Meanwhile, BMI, an indicator of obesity that is associated with blood lactate, was not related with MCI, indicating that the association between blood lactate and MCI is independent of obesity.

There are some limitations in this study. First, the range of age in this study population was wide, from 18 to 88 years. Since cognitive impairment occurs more frequently among the elderly people, age may bias the results of the study. Second, only the MMSE was used to evaluate cognitive function. Combined with the other tests of cognitive function (such as the Montreal cognitive assessment) will help to make a strong link with levels of lactate in the future study. Third, despite adjustment for all major confounders, we cannot exclude the possibility of residual confounding factors. Finally, this is a cross-sectional study; however, it was not possible to determine whether increased blood lactate is a cause or consequence of systemic inflammation and MCI. Therefore, longitudinal studies are needed to identify the causal relationship.

Conclusions

Our results suggest that plasma lactate levels are associated with systemic inflammation and MCI in this community-based cross-sectional study. Lactate deserves greater attention in the study of cognitive dysfunction.

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Compliance with ethical standards

This study was approved by the Research Ethics Committee of Sun Yat-sen Memorial Hospital, Sun Yat-sen University. All participants provided written informed consent.

Conflict of interest The authors declare that they have no competing interests.

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