



## Body Mass Index and Mild Cognitive Impairment Among Middle-Aged and Older Adults from Low- and Middle-Income Countries

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## BMI and MCI among middle aged and older adults

1 **Title:** Body mass index and mild cognitive impairment among middle-aged and older adults  
2 from low- and middle-income countries

3

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BMI and MCI among middle aged and older adults

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30 **ABSTRACT**

31 **Background:** The effect of weight modification on future dementia risk is currently a subject  
32 of debate, and may be modified by age. Thus, the aim of the present study was to investigate  
33 the association between body mass index (BMI) status with mild cognitive impairment (MCI)  
34 (a preclinical stage of dementia) in middle-aged and older adults residing in six low- and  
35 middle-income countries (LMICs) using nationally representative data.

36 **Methods:** Cross-sectional data from the Study on Global Ageing and Adult Health (SAGE)  
37 were analysed. MCI was defined using the National Institute on Aging-Alzheimer's  
38 Association criteria. BMI ( $\text{kg}/\text{m}^2$ ) was based on measured weight and height and categorized  
39 as: underweight ( $<18.5$ ), normal ( $18.5-24.9$ ), overweight ( $25.0-29.9$ ), and obese ( $\geq 30.0$ ).  
40 Multivariable logistic regression analysis and meta-analysis were conducted to assess  
41 associations.

42 **Results:** Data on 32,715 individuals aged  $\geq 50$  years with preservation in functional abilities  
43 were analysed [mean (SD) age 62.1 (15.6) years; 51.7% females]. Among those aged 50-64  
44 years, compared to normal weight, underweight (OR=1.44; 95%CI=1.14-1.81), overweight  
45 (OR=1.17; 95%CI=1.002-1.37), and obesity (OR=1.46; 95%CI=1.09-1.94) were all  
46 significantly associated with higher odds for MCI. In those aged  $\geq 65$  years, underweight  
47 (OR=0.71; 95%CI=0.54-0.95) and overweight (OR=0.72; 95%CI=0.55-0.94) were associated  
48 with significantly lower odds for MCI, while obesity was not significantly associated with  
49 MCI.

50 **Conclusions:** The results of the study suggest that the association between BMI and MCI is  
51 likely moderated by age. Future longitudinal studies are required to confirm or refute the  
52 present findings before recommendations for policy and practice can be made.

53

54 **Key words:** Key terms: cognitive dysfunction, obesity, body mass index, aged.

55 **INTRODUCTION**

56 Dementia is an umbrella term used to describe a collection of syndromes that result in  
57 impaired ability to remember, think, or make decisions that interferes with performing  
58 everyday activities [1]. Globally, approximately 50 million people have dementia and  
59 approximately 60% of those with dementia reside in low- and middle-income countries  
60 (LMICs) [2]. Dementia is a significant global problem as it is a major cause of disability and  
61 dependency among older people worldwide. For example, in 2015, the total global societal  
62 cost of dementia was estimated to be US\$ 818 billion, equivalent to 1.1% of global gross  
63 domestic product (GDP) [2]. Since there are currently no disease modifying treatments for  
64 dementia [3] there is the need to identify modifiable risk factors for the preclinical  
65 transitional stages of dementia such as mild cognitive impairment (MCI).

66

67 MCI is an early stage of memory loss or other cognitive ability loss (such as language or  
68 visual/spatial perception) in individuals who maintain the ability to independently perform  
69 most activities of daily living [4]. It is important to note that there is no specific test for the  
70 diagnosis of MCI and a judgement is usually made based on the following criteria: (a)  
71 problems with memory or another mental function; (b) mental function has declined over  
72 time; (c) daily activities are generally not impaired; (d) mental status testing shows a mild  
73 level of impairment for age and education level; and (e) diagnosis is not dementia [5]. MCI  
74 has a high progression rate to dementia (12%, 20%, and 50% at 1, 3, and 5 years,  
75 respectively) [6], and is increasingly being considered an important stage for intervention to  
76 prevent or delay the onset of dementia.

77

78 There is currently growing interest in body mass index (BMI; particularly overweight and  
79 obesity) as a risk factor for MCI or dementia. A recent meta-analysis including longitudinal

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80 studies from high-income countries found that high BMI in mid-life is associated with greater  
81 risk for dementia onset, but that the opposite is true in late life [7]. This suggests that weight  
82 reduction, only in mid-life, may lead to lower dementia risk. In a more recent large  
83 epidemiological study including 1,349,857 dementia-free middle-aged participants from 39  
84 cohort studies, it was concluded that the association between BMI and dementia is likely to  
85 be attributable to two different processes: (1) a harmful effect of higher BMI, which is  
86 observable in long follow-up, and (2) a reverse-causation effect that makes a higher BMI to  
87 appear protective when the follow-up is short [8]. In another recent study of 3632 US  
88 participants aged 20 to 60 years, it was found that each 1 kg/m<sup>2</sup> increase in BMI at 40-49  
89 years was associated with higher risk of dementia, but lower risk after 70 years [9].

90

91 It is possible that high adiposity leads to cognitive impairment via a range of potential  
92 mechanisms including impaired cerebral metabolism [10], elevated leptin [11], inflammation  
93 and neuronal degradation [12]. On the other hand, being underweight may also be a risk  
94 factor for MCI or dementia via frailty and undernutrition [13,14].

95

96 However, there are only a small number of studies on the association between BMI and MCI  
97 (a critical stage to intervene to prevent dementia), with most studies being of small sample  
98 size and from high-income settings, despite the fact that dementia is expected to increase  
99 rapidly in low-economic regions [2]. Moreover, current data suggests that the prevalence of  
100 MCI in LMICs is high. For example, a recent systematic review found that in LMICs, the  
101 prevalence of amnesic MCI using the Petersen criteria ranged from 0.6% to 22.3%. Similar  
102 variability existed across studies using the International Working Group Criteria for amnesic  
103 MCI (range 4.5%to 18.3%) and all-MCI (range 6.1%to 30.4%)[15]. In addition, the number  
104 of people with overweight and obesity is increasing in LMICs [16] and the prevalence of

105    undernutrition is high [17]. Thus, data that can shed light on the potential role of weight  
106    modification on MCI/dementia prevention in this setting is of substantial importance. Given  
107    this background, the aim of the present study was to investigate the association between BMI  
108    status (i.e., underweight, overweight, obesity) with MCI in 32,715 middle-aged and older  
109    adults residing in six LMICs.

110

## 111    **METHODS**

### 112    *The survey*

113    Data from the Study on Global Ageing and Adult Health (SAGE) were analysed. These data  
114    are publicly available through: <http://www.who.int/healthinfo/sage/en/>. This survey was  
115    undertaken in China, Ghana, India, Mexico, Russia, and South Africa between 2007 and  
116    2010. These countries broadly represent different geographical locations and levels of socio-  
117    economic and demographic transition. Based on the World Bank classification at the time of  
118    the survey, Ghana was the only low-income country, and China and India were lower middle-  
119    income countries although China became an upper middle-income country in 2010. The  
120    remaining countries were upper middle-income countries.

121        Details of the survey methodology have been published elsewhere [18]. Briefly, in  
122    order to obtain nationally representative samples, a multistage clustered sampling design  
123    method was used. The sample consisted of adults aged  $\geq 18$  years with oversampling of those  
124    aged  $\geq 50$  years. Trained interviewers conducted face-to-face interviews using a standard  
125    questionnaire. Standard translation procedures were undertaken to ensure comparability  
126    between countries. The survey response rates were: China 93%; Ghana 81%; India 68%;  
127    Mexico 53%; Russia 83%; and South Africa 75%. Sampling weights were constructed to  
128    adjust for the population structure as reported by the United Nations Statistical Division [19].

129 Ethical approval was obtained from the WHO Ethical Review Committee and local ethics  
130 research review boards. Written informed consent was obtained from all participants.

131

132 ***Mild cognitive impairment***

133 MCI was ascertained based on the recommendations of the National Institute on Aging-  
134 Alzheimer's Association [20]. We applied the identical algorithms used in previous SAGE  
135 publications using the same survey questions to identify MCI [21,22]. Briefly, individuals  
136 fulfilling all of the following conditions were considered to have MCI:

137 (a) Concern about a change in cognition: Individuals who replied 'bad' or 'very bad' to the  
138 question "How would you best describe your memory at present?" and/or those who  
139 answered 'worse' to the question "Compared to 12 months ago, would you say your memory  
140 is now better, the same or worse than it was then?" were considered to have this condition.

141 (b) Objective evidence of impairment in one or more cognitive domains: was based on a  $<-1$   
142 SD cut-off after adjustment for level of education, age, and country. Cognitive function was  
143 assessed through the following performance tests: word list immediate and delayed verbal  
144 recall from the Consortium to Establish a Registry for Alzheimer's Disease [23], which  
145 assessed learning and episodic memory; digit span forward and backwards from the Weschler  
146 Adult Intelligence Scale [24], that evaluated attention and working memory; and the animal  
147 naming task [23], which assessed verbal fluency.

148 (c) Preservation of independence in functional abilities: was assessed by questions on self-  
149 reported difficulties with basic activities of daily living (ADL) in the past 30 days [25].  
150 Specific questions were: "How much difficulty did you have in getting dressed?" and "How  
151 much difficulty did you have with eating (including cutting up your food)?" The answer  
152 options were none, mild, moderate, severe, and extreme (cannot do). Those who answered  
153 either none, mild, or moderate to both of these questions were considered to have



154 preservation of independence in functional activities. All other individuals were deleted from  
155 the analysis (935 individuals aged  $\geq 50$  years).

156 (d) No dementia: Individuals with a level of cognitive impairment severe enough to preclude  
157 the possibility to undertake the survey were not included in the current study.

158

### 159 ***Body mass index (BMI)***

160 Height was measured using a stadiometer, and weight was measured using an electronic  
161 weighing scale that was periodically calibrated. Weight and height measurements were taken  
162 with participants wearing only one layer of clothes and with their shoes off; height was  
163 recorded to the nearest 0.1 cm with a stadiometer, while weight was measured to the nearest  
164 0.1 kg with a weighting scale. BMI was calculated as weight in kilograms divided by height  
165 in meters squared based on measured weight and height, and classified as underweight  
166 (BMI $<18.5$  kg/m<sup>2</sup>), normal weight (BMI 18.5-24.9 kg/m<sup>2</sup>), overweight (BMI 25.0-29.9  
167 kg/m<sup>2</sup>), and obesity (BMI $\geq 30$  kg/m<sup>2</sup>) in line with WHO guidelines [26].

168

### 169 ***Control variables***

170 The control variables were selected based on past literature [27] and included age, sex,  
171 wealth quintiles based on income, years of education received, physical activity, alcohol use,  
172 smoking (never, current, former), depression, anxiety, sleep problems, diabetes, hypertension,  
173 and stroke. Levels of physical activity were assessed with the Global Physical Activity  
174 Questionnaire and were classified as low, moderate, and high based on conventional cut-offs  
175 [28]. Consumers of at least four (females) or five drinks (males) of any alcoholic beverage  
176 per day on at least one day in the past week were considered to be 'heavy' drinkers. Those  
177 who had ever consumed alcohol but were not heavy drinkers were categorized as 'non-heavy'  
178 drinkers [29]. Questions based on the World Mental Health Survey version of the Composite

179 International Diagnostic Interview [30] were used for the endorsement of past 12-month  
180 DSM-IV depression [31]. Those who claimed to have severe/extreme problems with worry or  
181 anxiety in the past 30 days were considered to have anxiety [32]. Sleep problems were  
182 assessed by the question “Overall in the last 30 days, how much of a problem did you have  
183 with sleeping, such as falling asleep, waking up frequently during the night or waking up too  
184 early in the morning?” and those answering severe or extreme were considered to have sleep  
185 problems [33]. Stroke and diabetes were based solely on self-reported lifetime diagnosis.  
186 Hypertension was defined as having at least one of: systolic blood pressure  $\geq 140$  mmHg;  
187 diastolic blood pressure  $\geq 90$  mmHg; or self-reported diagnosis.

188

### 189 *Statistical analysis*

190 The statistical analysis was performed with Stata 14.1 (Stata Corp LP, College station,  
191 Texas). The analysis was restricted to those aged  $\geq 50$  years. The middle-aged were also  
192 included in our study as from the point of prevention of dementia, intervening in middle-age  
193 is now considered important [34], especially that cognitive dysfunction can manifest up to 10  
194 years before a dementia diagnosis [35]. The analysis was stratified by age (i.e., middle-aged  
195 50-64 years and older adults  $\geq 65$  years) as a previous study showed that the association  
196 between BMI and MCI may differ between these age groups [27]. Multivariable logistic  
197 regression analysis was conducted to assess the association between BMI (independent  
198 variable with normal weight as the reference category) and MCI (dependent variable) using  
199 country-wise samples while simultaneously adjusting for age, sex, wealth, education,  
200 physical activity, alcohol use, smoking, depression, anxiety, sleep problems, diabetes,  
201 hypertension, and stroke. The Higgins’s  $I^2$  based on estimates from each country was also  
202 calculated in order to assess between-country heterogeneity. The Higgins’s  $I^2$  represents the  
203 degree of heterogeneity that is not explained by sampling error with a value of  $<40\%$  often

204 considered as negligible and 40-60% as moderate heterogeneity [36]. A pooled estimate was  
205 obtained by random-effects meta-analysis.

206 The sample weighting and the complex study design were taken into account in the  
207 analyses. Results from the regression analyses are presented as odds ratios (ORs) with 95%  
208 confidence intervals (CIs). The level of statistical significance was set at  $P < 0.05$ .

209

## 210 RESULTS

211 The final sample included 32,715 individuals (China  $n=12815$ ; Ghana  $n=4201$ ; India  $n=6191$ ;  
212 Mexico  $n=2070$ ; Russia  $n=3766$ ; South Africa  $n=3672$ ) aged  $\geq 50$  years with preservation in  
213 functional abilities. There were 19092 individuals between the ages of 50 and 64 (63.3%),  
214 and 13623 aged  $\geq 65$  years (36.7%). Overall, the mean (SD) age was 62.1 (15.6) years while  
215 51.7% were females. The overall prevalence of MCI was 15.3%, while that of underweight,  
216 normal weight, overweight, and obesity was 16.2%, 47.8%, 24.5%, and 11.5%, respectively.  
217 The sample characteristics by country are provided in **Table 1**. The prevalence of MCI  
218 ranged from 7.4% in Ghana to 24.3% in China, while the prevalence of underweight and  
219 obesity were particularly high in India (38.4%) and South Africa (46.6%), respectively.

220

221 The association between underweight (vs. normal weight) weight is shown in **Figure 1**.  
222 Among those aged 50-64 years, overall, underweight was associated with a significant 1.44  
223 (95%CI=1.14-1.81;  $I^2=0.0\%$ ) times higher odds for MCI, while for those aged  $\geq 65$  years,  
224 underweight was significantly associated with lower odds for MCI [0.71 (95%CI=0.54-0.95;  
225  $I^2=19.5\%$ )]. In terms of overweight (vs. normal weight), among the middle-aged, overweight  
226 was significantly associated with higher odds for MCI [OR=1.17 (95%CI=1.002-1.37;  
227  $I^2=0.0\%$ )], and among older adults, overweight was significantly associated with lower odds  
228 for MCI [0.72 (95%CI=0.55-0.94;  $I^2=26.8\%$ )] (**Figure 2**). As for obesity (vs. normal weight),

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229 this was associated with a significantly higher odds for MCI among the middle-aged  
230 (OR=1.46; 95%CI=1.09-1.94;  $I^2=5.5\%$ ), but this was not significantly associated with MCI  
231 among older adults (**Figure 3**).

232

## 233 **DISCUSSION**

### 234 *Main findings*

235 Results from this large multi-country sample of middle-aged and older age adults showed that  
236 in middle-aged adults, underweight, overweight, and obesity are significantly associated with  
237 higher odds for MCI when compared to normal weight. In contrast, in older adults,  
238 underweight and overweight were associated with significantly lower odds for MCI.  
239 Although obesity was associated with 0.74 (95%CI=0.49-1.14) times lower odds for MCI in  
240 older adults, this was not statistically significant. The level of between-country heterogeneity  
241 in these associations was in general low.

242

### 243 *Interpretation of the findings*

244 One meta-analysis including longitudinal data found that overweight and obesity in middle-  
245 age was associated with a non-significant 1.10 (95%CI=0.99-1.22) and a significant 1.41  
246 (95%CI=1.20-1.60) times higher risk for dementia onset, respectively. In older adults,  
247 overweight was non-significantly (RR=0.88; 95%CI=0.74-1.02) and obesity significantly  
248 (RR=0.83; 95%CI=0.74-0.94) associated with lower odds for dementia onset [5]. Our results  
249 are somewhat similar to the results of this meta-analysis, and add to this previous literature  
250 by suggesting that weight reduction in middle-aged adults who are overweight may  
251 potentially lead to a reduced dementia risk in LMICs. In addition, our finding that  
252 underweight was associated with higher odds for MCI in middle-aged adults supports one  
253 previous longitudinal study that identified that underweight in mid-life is positively

254 associated with dementia [37]. More research is needed to test whether addressing  
255 overweight and obesity may lead to decreased risk for future MCI/dementia onset, and  
256 whether maintenance of normal weight in middle-aged adults may be particularly important  
257 in LMICs.

258

259 The finding that overweight/obesity was associated with higher odds for MCI in the middle-  
260 aged may be explained by mechanisms that cause brain volume reduction such as  
261 inflammation, cardiovascular risk factors, and low physical activity [7]. As for the lower odds  
262 for MCI in older individuals with overweight observed in our study, there are several  
263 hypotheses that may explain this. First, overweight that occurs in older adulthood (following  
264 periods of relatively normal weight throughout middle-age) may impact cognition less than  
265 being overweight starting in middle age or earlier in the life course [38]. Second, older adults  
266 who have a higher BMI are often less likely to have frailty or other comorbidities, and this  
267 may have a protective effect on cognitive impairment [39].

268

269 The higher odds for MCI among underweight middle-aged individuals may be explained by  
270 several factors. First, underweight in middle-age may be associated with eating disorders, and  
271 these have been found to affect memory function. For example, anorexia nervosa is  
272 associated with disruption of functioning of the visuo-spatial sketch pad and central executive  
273 components of working memory [40]. Next, underweight may be associated with  
274 undernutrition, which is associated with cognitive impairment via micronutrient and  
275 macronutrient deficiency [41,42]. Finally, underweight may be a sign of the presence of other  
276 comorbidities or frailty, which can increase risk for cognitive decline, but were not assessed  
277 in the present study [43]. As for the finding that underweight was associated with lower odds  
278 for MCI in older adults, mechanistic and epidemiologic evidence suggests that MCI or

279 dementia may cause involuntary weight loss well before its clinical onset [37], and low BMI  
280 may spuriously appear to be protective against MCI or dementia.

281

### 282 ***Public health implications and areas for future research***

283 Findings from the present study suggest that maintenance of normal weight only in mid-life  
284 may possibly lead to lower MCI and dementia risk in LMICs. In the context of LMICs and to  
285 achieve weight reduction in mid-life for people with overweight/obesity, lifestyle  
286 interventions that includes both diet and physical activity components may be most effective  
287 [44]. Moreover, action planning and self-monitoring of outcomes of behavior have been  
288 found to achieve best results, and thus any lifestyle intervention to achieve weight loss in this  
289 setting should consider embedding such techniques [45]. The Exercise is Medicine Global  
290 Initiative is designed to support health care professionals in prescribing exercise for patients  
291 by training providers to assess patient physical activity levels, imparting behavioral  
292 counseling to increase activity using change models, and referring patients to resources to  
293 facilitate physical activity[46]. Importantly, this initiative already exists in LMICs, and  
294 evaluation of its impact will provide important data on how to adapt and scale up this  
295 program to encourage healthy activity levels and weight status[47].

296

### 297 ***Strength and limitations***

298 The large sample of middle-aged and older adults across six LMICs is a clear strength of the  
299 present study. However, findings from this study must be interpreted in light of the study  
300 limitations. First, the study was cross-sectional in nature, and therefore, temporal associations  
301 or causality cannot be established. Clearly, future longitudinal and intervention studies are  
302 necessary to understand the mechanisms that underlie the associations observed and to clarify  
303 the effect of weight modification on future risk of MCI or dementia.

304 Second, we did not have information on weight trajectories over the life course, despite the  
305 fact that this has also been reported to be important in determining risk for MCI/dementia.  
306 Third, participants with mild forms of dementia could have been included in our study  
307 sample as the study did not include a clinical assessment of dementia. Fourth, we did not  
308 have information on nutritional factors, while the data on physical activity used in our study  
309 was only on current levels of physical activity. Physical activity during the life course and  
310 nutritional factors are known to influence BMI, and also risk for MCI or dementia [48,49]  
311 and thus, residual confounding is possible. Fifth, the use of BMI as an exposure may be a  
312 further limitation as BMI does not measure adiposity (although heavily correlated) or fat free  
313 mass [50]. Indeed, this may lead to some data distortion in older adults as more fat free  
314 muscle mass is associated with less cognitive issues [51]. Finally, the countries included in  
315 the study were not randomly selected. Thus, the results are not generalizable to all LMICs or  
316 high-income countries

317

### 318 *Conclusions*

319 In this large sample of middle-aged and older adults from six LMICs, it was found that  
320 underweight, overweight, and obesity are significantly associated with higher odds for MCI  
321 in the middle-aged, but that underweight and overweight are associated with significantly  
322 lower odds for MCI in older adults. These findings add to the current debate on whether  
323 weight modification has a role in the prevention of dementia.

324

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330

331 **Conflict of Interest**

332 The authors have no conflict of interest to report.

333

334 **Tables and Figures**



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**Table 1** Sample characteristics by country

Characteristic		Country					
		China	Ghana	India	Mexico	Russia	South Africa
Mild cognitive impairment	Yes	24.3	7.4	9.7	17.6	9.6	8.5
Body mass index (kg/m <sup>2</sup> )	Underweight	4.3	15.1	38.4	0.6	0.9	2.9
	Normal	60.4	55.2	48.4	21.2	23.8	24.0
	Overweight	29.5	19.8	10.7	49.7	40.8	26.5
	Obese	5.9	9.9	2.5	28.5	34.5	46.6
Age (years)	Mean (SD)	62.3 (16.3)	64.2 (19.7)	61.1 (13.2)	62.3 (17.4)	63.4 (14.8)	61.4 (18.3)
Sex	Female	50.2	47.4	48.2	52.8	60.6	56.0
Education (years)	Mean (SD)	5.6 (8.1)	4.2 (9.9)	3.8 (7.4)	5.1 (7.9)	11.2 (5.1)	6.1 (10.1)
Physical activity	High	43.8	62.4	53.5	41.4	59.0	28.5
	Moderate	27.7	12.5	23.1	22.3	15.9	12.7
	Low	28.5	25.2	23.4	36.3	25.1	58.7
Alcohol consumption	Never	67.5	43.4	84.8	48.3	28.4	76.3
	Non-heavy	25.5	54.4	14.6	46.7	66.2	19.9

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	Heavy	7.0	2.2	0.6	5.0	5.4	3.8
Smoking	Never	64.2	75.3	45.2	60.3	69.3	66.6
	Smoker	29.3	10.7	50.4	20.5	21.8	23.8
	Quit	6.5	14.0	4.3	19.3	8.9	9.7
Depression	Yes	1.0	7.0	11.9	10.2	3.2	2.9
Anxiety	Yes	0.6	6.5	16.0	4.6	3.3	9.3
Sleep problems	Yes	2.7	6.8	12.4	5.0	8.3	8.6
Diabetes	Yes	6.5	3.6	6.8	17.1	6.8	9.1
Hypertension	Yes	60.5	59.3	36.7	61.5	71.7	78.6
Stroke	Yes	2.9	2.2	1.7	3.7	4.4	3.4

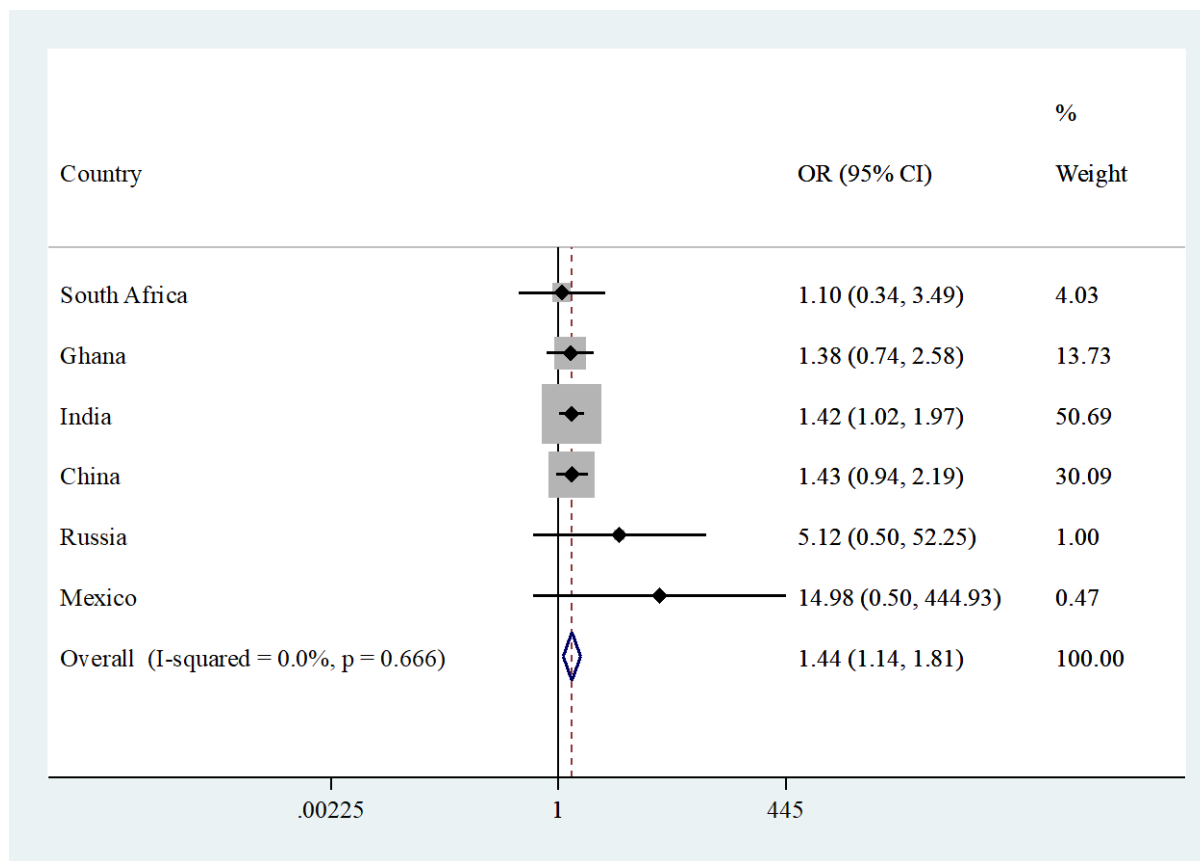
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335 Abbreviation: SD Standard deviation

336 Data are % unless otherwise stated.

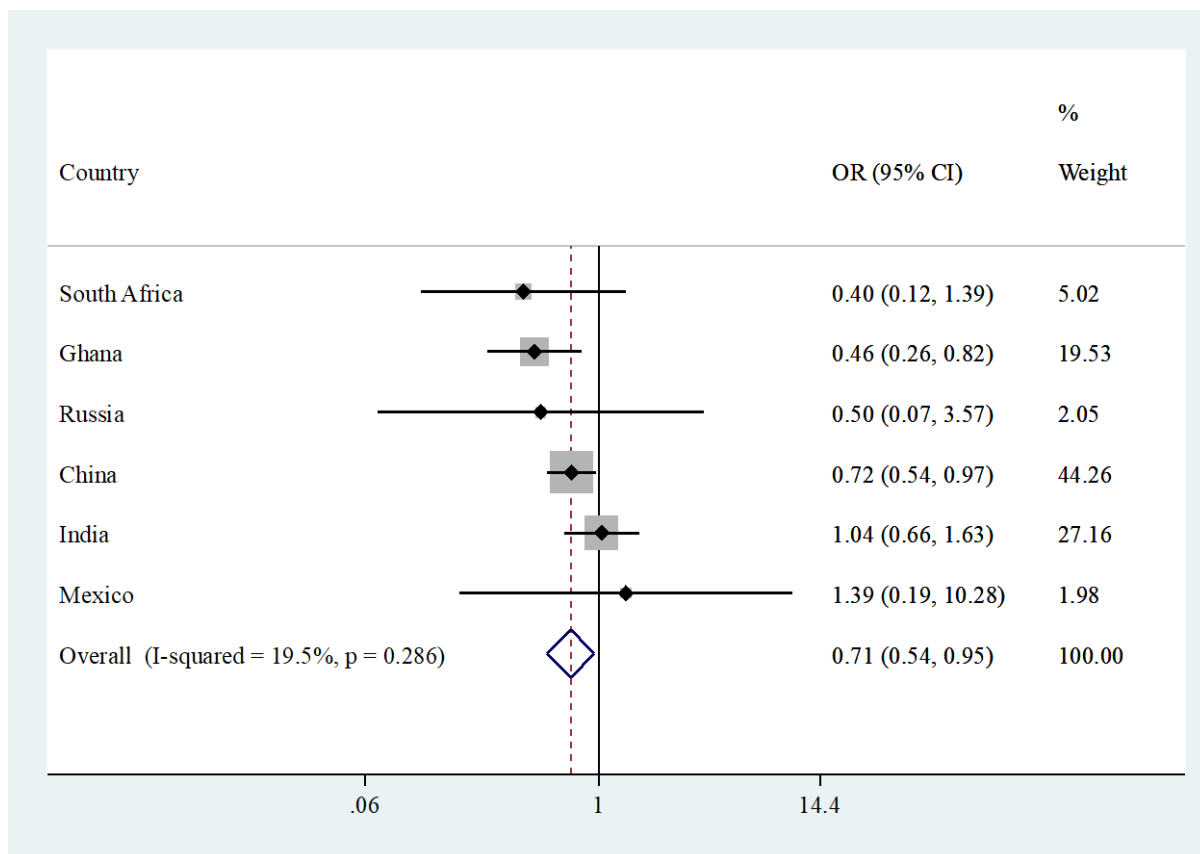
BMI and MCI among middle aged and older adults

337 (A) Age 50-64 years



338

339 Graph(B) Age ≥65 years

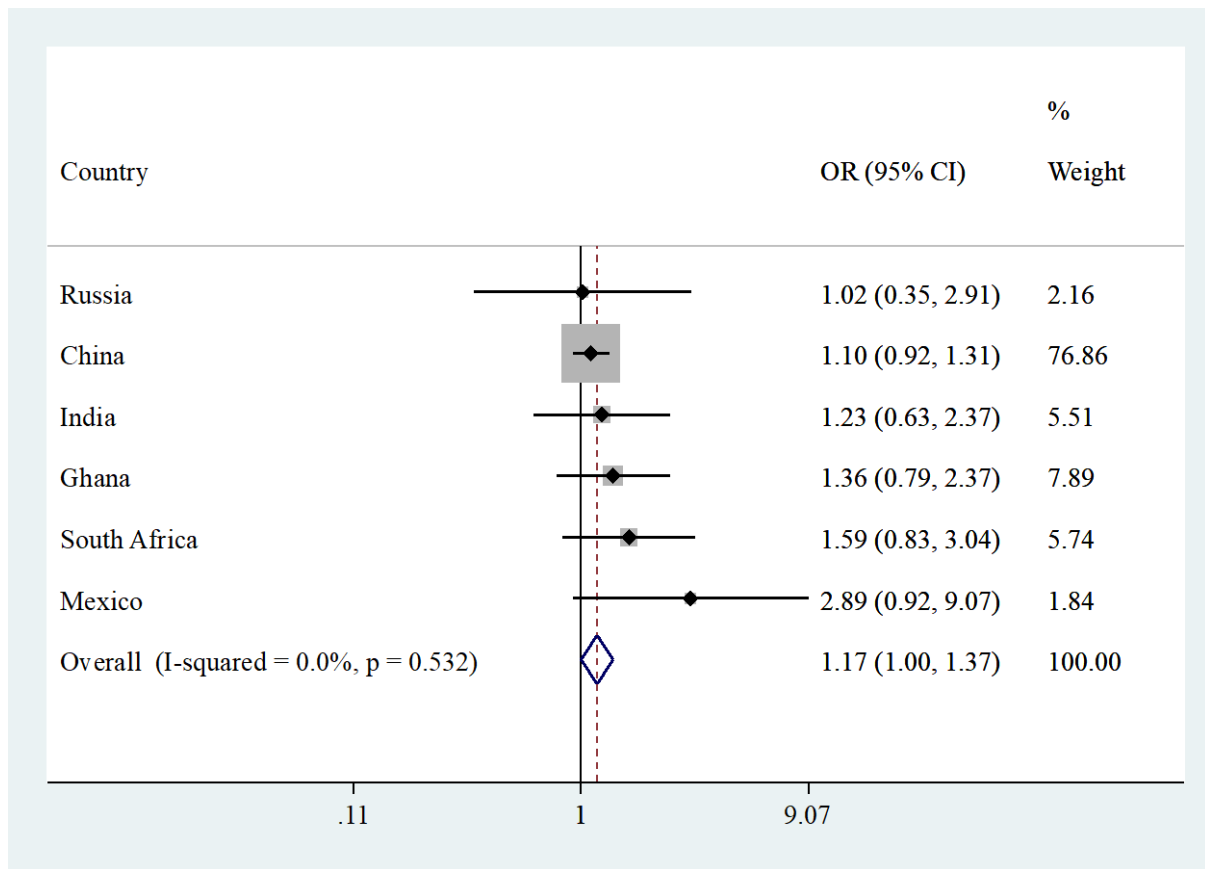


## BMI and MCI among middle aged and older adults

- 340 **Figure 1** Country-wise association between underweight (vs. normal weight) among people  
341 aged (A) 50-64 years and (B)  $\geq 65$  years estimated by multivariable logistic regression  
342 Abbreviation: OR Odds ratio; CI Confidence interval  
343 Models are adjusted for age, sex, wealth, education, physical activity, alcohol use, smoking, depression, anxiety,  
344 sleep problems, diabetes, hypertension, and stroke.  
345 Overall estimate was obtained by meta-analysis with random effects.

BMI and MCI among middle aged and older adults

346 (A) 50-64 years



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348 (B) ≥65 years

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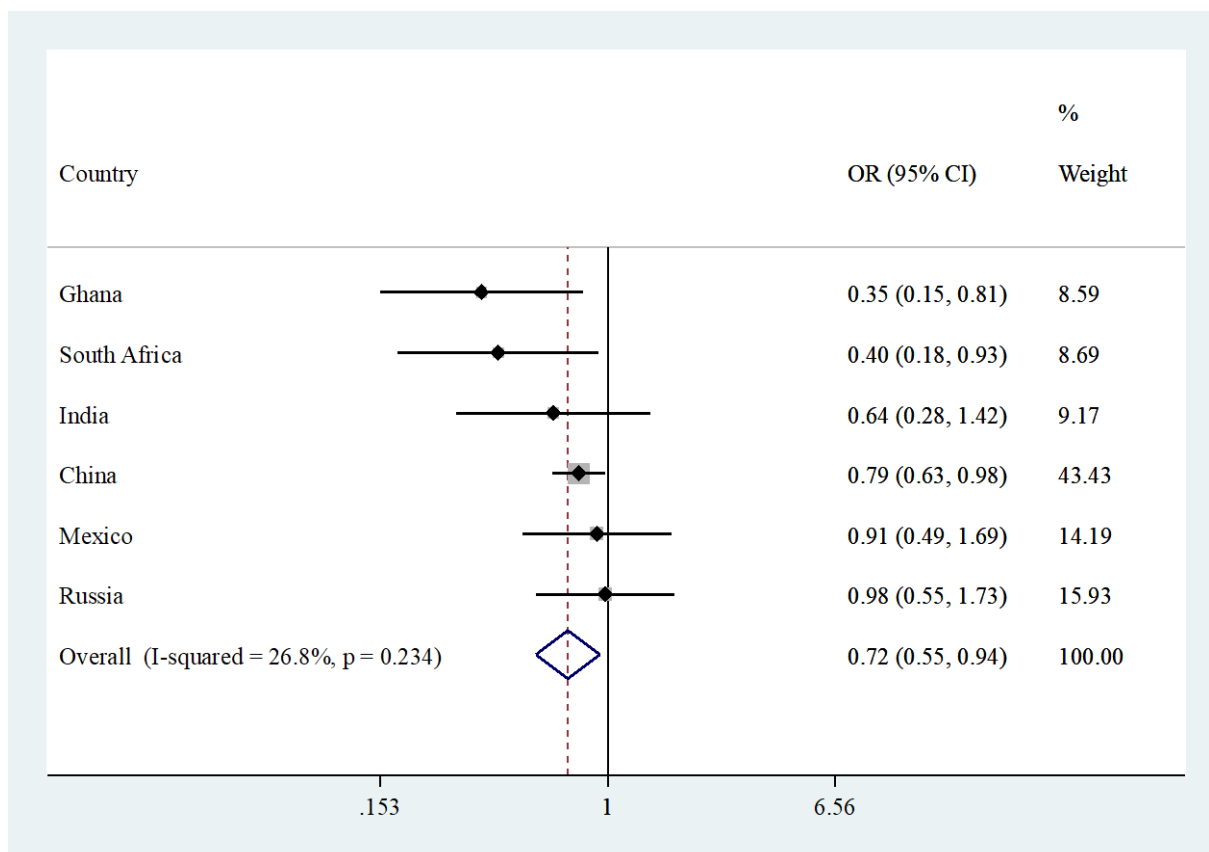
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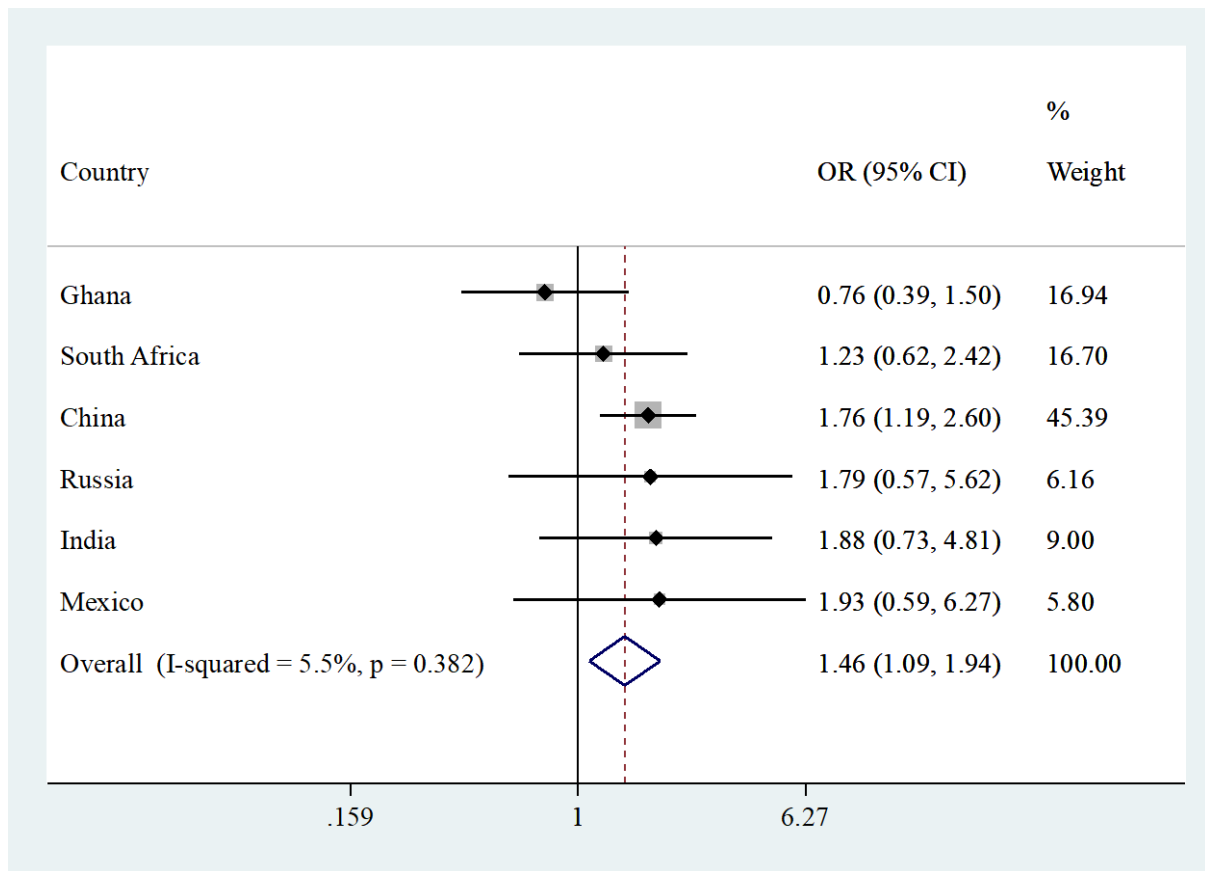


## BMI and MCI among middle aged and older adults

359 **Figure 2** Country-wise association between overweight (vs. normal weight) among people  
360 aged (A) 50-64 years and (B)  $\geq 65$  years estimated by multivariable logistic regression  
361 Abbreviation: OR Odds ratio; CI Confidence interval  
362 Models are adjusted for age, sex, wealth, education, physical activity, alcohol use, smoking, depression, anxiety,  
363 sleep problems, diabetes, hypertension, and stroke.  
364 Overall estimate was obtained by meta-analysis with random effects.

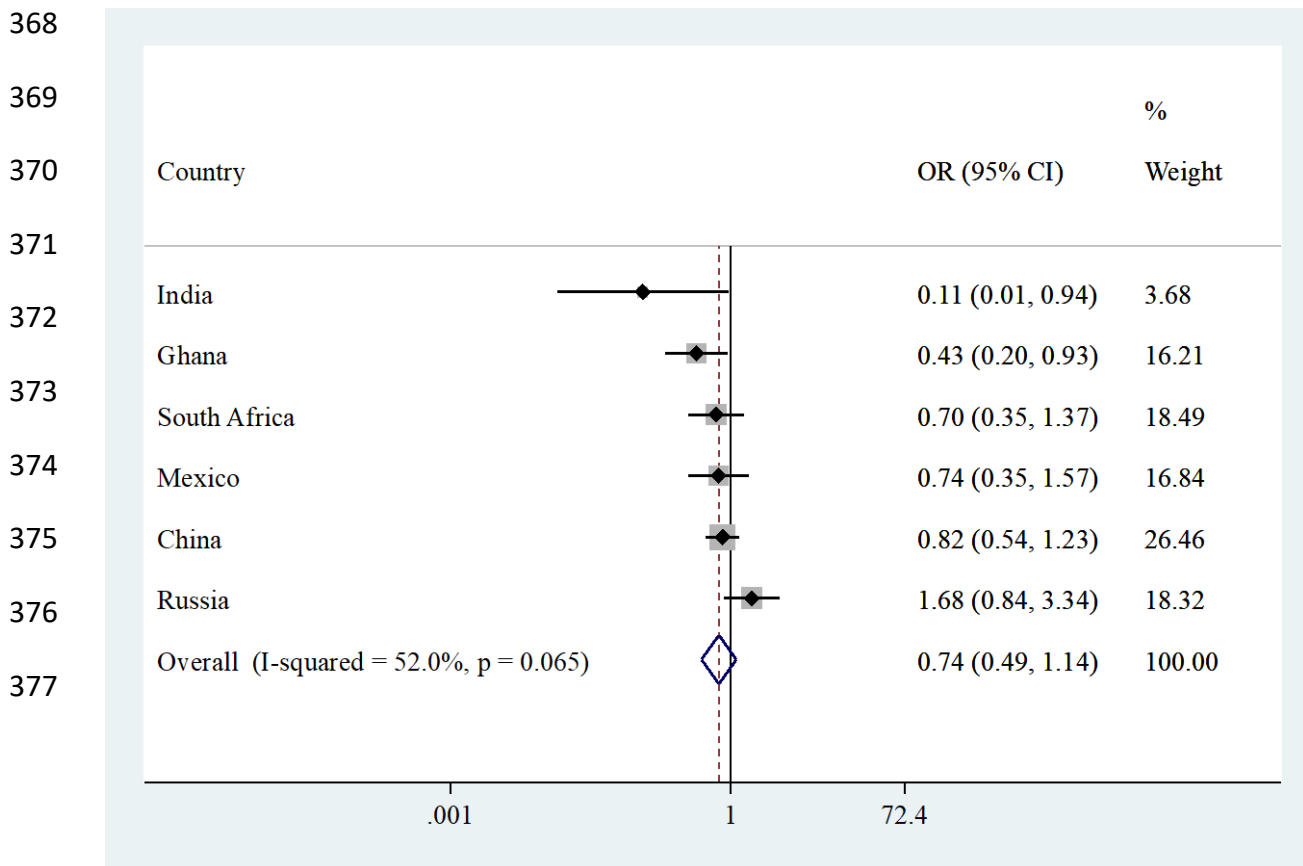
BMI and MCI among middle aged and older adults

365 (A) 50-64 years



366

367 (B) ≥65 years



377

378 **Figure 3** Country-wise association between obesity (vs. normal weight) among people aged  
379  $\geq 65$  years estimated by multivariable logistic regression  
380 Abbreviation: OR Odds ratio; CI Confidence interval  
381 Models are adjusted for age, sex, wealth, education, physical activity, alcohol use, smoking, depression, anxiety,  
382 sleep problems, diabetes, hypertension, and stroke.  
383 Overall estimate was obtained by meta-analysis with random effects.



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