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## Original Contribution

# Curry Consumption and Cognitive Function in the Elderly

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Curcumin, from the curry spice turmeric, has been shown to possess potent antioxidant and antiinflammatory properties and to reduce β-amyloid and plaque burden in experimental studies, but epidemiologic evidence is lacking. The authors investigated the association between usual curry consumption level and cognitive function in elderly Asians. In a population-based cohort ($n = 1,010$) of nondemented elderly Asian subjects aged 60–93 years in 2003, the authors compared Mini-Mental State Examination (MMSE) scores for three categories of regular curry consumption, taking into account known sociodemographic, health, and behavioral correlates of MMSE performance. Those who consumed curry "occasionally" and "often or very often" had significantly better MMSE scores than did subjects who "never or rarely" consumed curry. The authors reported tentative evidence of better cognitive performance from curry consumption in nondemented elderly Asians, which should be confirmed in future studies.

cognition; *Curcuma*; curcumin; dementia

Abbreviations: ADL, activities of daily living; CI, confidence interval; MMSE, Mini-Mental State Examination; NSAID, nonsteroidal antiinflammatory drug.

Antiinflammatory drugs and antioxidants are promising neuroprotective agents against Alzheimer's disease (1). Epidemiologic studies suggest that long-term use of nonsteroidal antiinflammatory drugs (NSAIDs) is associated with a reduced risk of Alzheimer's disease (2). However, gastrointestinal, liver, and kidney toxicity limits their use in the elderly. Antioxidants, such as vitamin E, protect neurons from β-amyloid toxicity in vitro but have shown limited clinical success in ameliorating cognitive decline in patients with mild and moderate Alzheimer's disease (3), as well as increased cardiovascular and mortality risks (4).

Mounting evidence suggests that curcumin (1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-2,5-dione) and other products from turmeric, the dried rhizome of *Curcuma longa*, may be useful for the prevention and/or treatment of some age-related degenerative disorders. Turmeric, commonly known as a yellow curry spice, is used widely among Asians as a food flavoring and preservative and as a herbal remedy for the treatment of coryza, hepatic disorders, and rheumatism (5). Curcumin and other products isolated from turmeric are well known to possess potent antiinflammatory and antioxidant properties (6, 7). It inhibits in vitro lipid peroxidation of the brain (8–10), scavenges nitric oxide-based radicals (11), and is several times more potent than vitamin E as a free radical scavenger (12). Curcuminoids have also been shown to be powerful antiatherogenic agents. Recent data (13) indicate that, in healthy human subjects, the daily intake of 200 mg of curcumin and other extracts lowers total blood lipid peroxides, as well as high density and low density lipoprotein lipid peroxidation, and promotes antioxidant-induced normalization of the plasma levels of fibrinogen and of the apolipoprotein B/apolipoprotein A

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**TABLE 1. Description of subjects according to levels of curry consumption, Singapore National Mental Health Survey, 2003**

| | Curry consumption* | | | | ANOVA† *p* value |
|---|---|---|---|---|---|
| | Total ($n$ = 1,010) | Never/rarely ($n$ = 163) | Occasionally ($n$ = 411) | Often ($n$ = 436) | |
| Age, years (mean (SD†)) | 68.9 (6.8) | 70.9 (8.2) | 68.9 (6.6) | 68.2 (6.2) | |
| Female gender (%) | 52.7 | 53.9 | 55.0 | 50.3 | 0.38 |
| Ethnicity (%) | | | | | |
| Chinese | 47.1 | 69.1 | 63.4 | 23.6 | |
| Malay | 31.5 | 27.3 | 27.8 | 36.6 | |
| Indian | 21.4 | 3.6 | 8.7 | 39.8 | <0.01 |
| Education (%) | | | | | |
| None | 34.5 | 46.7 | 37.3 | 27.7 | |
| Primary level, 1–6 years | 41.3 | 32.7 | 42.1 | 43.2 | |
| Secondary or above, ≥7 years | 21.2 | 20.6 | 20.6 | 29.1 | <0.01 |
| Functional disability (%) | | | | | |
| None | 65.5 | 61.8 | 66.6 | 65.2 | |
| ≥1 IADL† dependence only | 24.2 | 25.5 | 24.2 | 23.6 | |
| ≥1 BADL† dependence | 10.3 | 12.7 | 9.2 | 11.2 | 0.69 |
| Social activities score levels (%) | | | | | |
| 0–2 | 44.7 | 57.0 | 43.1 | 41.9 | |
| 3–5 | 46.4 | 32.1 | 48.7 | 49.4 | |
| ≥6 | 8.9 | 10.9 | 8.2 | 8.7 | 0.003 |
| Productive activities score levels (%) | | | | | |
| 0–2 | 30.9 | 43.6 | 30.1 | 27.5 | |
| 3–5 | 53.9 | 43.0 | 56.1 | 55.6 | |
| ≥6 | 15.1 | 13.3 | 13.8 | 16.9 | 0.003 |
| Fitness activities score levels (%) | | | | | |
| 0–2 | 51.7 | 60.0 | 52.3 | 48.3 | |
| 3–5 | 47.0 | 38.2 | 47.0 | 50.1 | |
| ≥6 | 7.3 | 1.8 | 0.7 | 1.6 | 0.07 |
| Depression (%) | 4.6 | 3.6 | 4.1 | 5.7 | 0.42 |
| Cardiovascular disease and risk factors (%) | | | | | |
| Hypertension | 45.9 | 47.9 | 47.5 | 43.5 | 0.43 |
| Dyslipidemia | 26.1 | 24.2 | 26.6 | 26.3 | 0.83 |
| Diabetes | 24.0 | 20.6 | 18.2 | 30.7 | <0.01 |
| Coronary artery disease/myocardial infarction | 13.5 | 11.5 | 12.3 | 15.1 | 0.37 |
| Congestive heart failure | 7.3 | 6.1 | 7.0 | 8.2 | 0.62 |
| Stroke | 5.0 | 9.7 | 4.1 | 4.1 | 0.011 |
| Asthma | 5.0 | 4.8 | 3.9 | 6.2 | 0.30 |
| Chronic obstructive pulmonary disease | 1.2 | 1.2 | 1.0 | 1.4 | 0.86 |
| Nonsteroidal antiinflammatory drug use (%) | | | | | |
| None or rarely | 61.8 | 65.5 | 65.6 | 56.9 | |
| Occasionally | 29.1 | 24.8 | 25.4 | 34.2 | |
| Frequently/regularly | 9.1 | 9.7 | 9.0 | 8.9 | 0.042 |
| Steroid use (%) | 1.0 | 0.6 | 1.2 | 0.9 | 0.78 |
| Hearing impairment (%) | 7.2 | 7.9 | 8.2 | 6.7 | 0.66 |
| Visual impairment (%) | 10.9 | 14.6 | 9.7 | 11.0 | 0.37 |
| Smoking (%) | | | | | |
| Former smokers | 8.3 | 7.3 | 5.6 | 11.2 | |
| Current smokers | 14.2 | 12.7 | 14.0 | 14.6 | 0.042 |
| Alcohol (%) | | | | | |
| Never or rarely | 90.2 | 88.4 | 91.5 | 90.1 | |
| Occasional and <1 drink daily | 8.1 | 9.7 | 7.2 | 8.3 | |
| ≥1 drink daily | 1.5 | 1.8 | 1.2 | 1.6 | 0.50 |

* Never or rarely (less than once in 6 months); occasionally (more than or once in 6 months but less than once a month); often (once a month or more, weekly, or daily).

† ANOVA, analysis of variance; SD, standard deviation; IADL, instrumental activities of daily living; BADL, basic activities of daily living.

**TABLE 2. Multivariate analysis of significant variables associated with Mini-Mental State Examination scores, Singapore National Mental Health Survey, 2003***

| Significant variables | Analysis of variance | | | Adjusted mean score | 95% confidence interval |
|---|---|---|---|---|---|
| | df | *F* value | *p* value | | |
| Overall | | | | 24.3 | 22.4, 26.2 |
| Age, years | 1 | 10.992 | 0.001 | | |
| <75 | | | | 24.8 | 22.9, 26.7 |
| ≥75 | | | | 23.8 | 21.9, 25.7 |
| Gender | 1 | 37.308 | <0.001 | | |
| Male | | | | 25.1 | 23.2, 27.0 |
| Female | | | | 23.5 | 21.6, 25.4 |
| Education | 2 | 46.102 | <0.001 | | |
| None | | | | 22.5 | 20.6, 24.4 |
| Primary level, 1–6 years | | | | 24.4 | 22.5, 26.3 |
| Secondary or above, ≥7 years | | | | 26.0 | 24.1, 27.9 |
| Ethnicity | 2 | 19.437 | <0.001 | | |
| Chinese | | | | 25.5 | 23.6, 27.3 |
| Malay | | | | 23.7 | 21.8, 25.6 |
| Indian | | | | 23.7 | 21.6, 25.8 |
| Functional disability | 2 | 32.094 | <0.001 | | |
| None | | | | 25.7 | 23.8, 27.6 |
| ≥1 IADL disability only | | | | 23.9 | 22.0, 25.8 |
| ≥1 BADL disability (with or without IADL disability) | | | | 23.3 | 21.4, 25.2 |
| Asthma | 1 | 12.806 | <0.001 | | |
| No | | | | 25.2 | 23.4, 27.1 |
| Yes | | | | 23.4 | 21.4, 25,4 |
| Coronary artery disease | 1 | 3.892 | 0.049 | | |
| No | | | | 24.6 | 22.8, 26.5 |
| Yes | | | | 23.9 | 22.0, 25.9 |
| Social activities score | 2 | 4.719 | 0.009 | | |
| 0–2 | | | | 23.7 | 21.9, 25.6 |
| 3–5 | | | | 24.3 | 22.5, 26.2 |
| ≥6 | | | | 24.8 | 22.8, 26.8 |
| Curry consumption | 2 | 3.673 | 0.023 | | |
| Never or rarely | | | | 23.3 | 21.2, 25.4 |
| Occasionally | | | | 24.8 | 22.9, 26.7 |
| Often | | | | 24.8 | 22.9, 26.6 |

* Model: $R^2 = 0.350$; covariates: age, gender, ethnicity, educational levels, instrumental activities of daily living (IADL)/basic activities of daily living (BADL) dependence (hierarchical levels), social activities (three levels), productive activities (three levels), fitness activities (three levels), visual impairment, hearing impairment, hypertension, dyslipidemia, coronary artery disease, congestive heart failure, diabetes, stroke, asthma, chronic obstructive pulmonary disease, depression, frequency of nonsteroidal antiinflammatory drug use, frequency of steroid use, alcohol consumption, smoking, and curry consumption; interaction: age × curry, gender × curry, ethnicity × curry, education × curry.

ratio, which are associated with reduced cardiovascular risk.

Another study (14) using an Alzheimer transgenic mouse model has shown that both low (160 ppm) and high (5,000 ppm) doses of dietary curcumin significantly lowered oxidized proteins and interleukin-1a, an inflammatory cytokine in the neuroinflammatory cascades involved in neuritic plaque formation in the brain. Notably, the study also showed that at low, but not high, doses, curcumin reduced insoluble and soluble β-amyloid and plaque burden by 43–50 percent.

In view of its efficacy and remarkably low toxicity, curcumin shows promise for the prevention of Alzheimer's disease. Thus far, no epidemiologic evidence exists to support a link between dietary curry consumption and lowered dementia risk or cognitive enhancement in the elderly. We present here tentative evidence that increased consumption of curry is associated with better cognitive performance in nondemented subjects.

## MATERIALS AND METHODS

The Singapore National Mental Health Survey of the Elderly is a population-based study of a nationally representative random sample of 1,092 older adults aged 60 or more years (72 percent response rate), conducted from February 15, 2003, to March 30, 2004. The multiethnic population of Singapore (total residents: 3 million) comprises 7.7 percent who are aged 65 or more years, of whom 83 percent are Chinese, 10 percent are Malays, and 7 percent are Indians. The survey used a sampling list of household addresses generated by probability sampling from the Department of Statistics' national database of dwellings in Singapore. The random sample was ethnically stratified with intentional oversampling of Malays (33 percent) and Indians (19 percent) for enhanced precision of ethnic-specific estimates. In each household of the sampling list, eligible subjects who were older adults aged 60 or more years and Singapore citizens or permanent residents were identified, and one subject per household was randomly selected. Extensive information was collected on personal, social, behavioral, and health-related variables that included detailed histories of medical conditions, medications, substance use, dietary intake including curry consumption, functional assessments, and semistructured diagnostic interviews for psychiatric disorders. The data were collected in the subjects' homes by trained nurses and field interviewers in English, Chinese, or Malay. Participating subjects gave written informed consent for the study, which was approved by the Ethics Committee of the Institute of Mental Health.

Subjects performed the Mini-Mental State Examination (MMSE) (15), a widely used instrument that provides a global measure of domains of cognitive function that included memory, attention, language, praxis, and visuospatial ability. The validity and reliability of the MMSE have been extensively studied (16), and the Chinese MMSE has been validated for use in Chinese populations in Shanghai (17) and Singapore (18). The Malay version of the MMSE was developed by forward and back translation from the English. The item on repeating a phrase in English "no ifs, ands, or buts" was replaced in the Chinese MMSE by "44 stone lions" and in the Malay version by "marah, merah, murah." The scale consists of 20 items, and scores range from 0 to 30, with higher scores indicating better cognitive functioning. The assumption of unidimensionality of the MMSE scale allows the use of MMSE as a summative score (19).

The level of self-reported usual frequency of curry consumption was quantified as "never or rarely" (never or less often than once in 6 months), "occasional" (more than or once in 6 months but less than once a month), "often" (more than or once a month but less than once a week), and "very often" (once a week or more, daily). Subjects in the last "very often" category were fewer and were combined with the "often" category of curry consumption. Curry is almost universally consumed as a gravy or soup in dishes among ethnic groups in Singapore. The most common curry dish in Singapore is "yellow" curries; "green" or "red" curries are seldom consumed. Curry consumption rich in turmeric was specified, to include only that which clearly imparted a rich yellow color to the gravy or soup (such as "korma" in Indian food or "lontong" in Malay dishes). As Asian dishes in Singapore are commonly spicy, interviewers were specially briefed to exclude foods that contained other spices without turmeric, such as hot chillies.

To take into account the potentially confounding influence of known correlates of cognitive impairment and dementia risk, we collected data for self-reported history of vascular conditions including hypertension, dyslipidemia, coronary artery disease, stroke and diabetes, asthma, chronic obstructive pulmonary disease, alcohol consumption and smoking, consumption of NSAIDs such as aspirin and ibuprofen, oral steroids, visual and hearing impairments, basic activities of living (Barthel Index (20)) and instrumental activities of living (so-called Lawton scales (21)), level of fitness, social and productive activities, and diagnoses of depression and dementia.

The level of fitness activities was assessed by the frequency of participation: "often" (at least 3 times a week) and "sometimes" (less often than 3 times a week and never or almost never) in exercise routines, walking, or active sports (three items). The levels of social and productive activities were assessed by the frequency of participation: "often" (at least once a week) and "sometimes" (less often than once a week and never or almost never) in entertainment, recreational, club, and religious activities (six items) and in vocational and self-development activities (five items). Subjects were categorized on their alcohol and smoking status as either those who daily consumed at least one alcoholic drink (one can of beer or equivalent amounts of other alcoholic drinks) or less and as current smokers, former smokers, and nonsmokers. Psychiatric disorders were diagnosed with a widely used and validated, semistructured diagnostic interview instrument, the Geriatric Mental State (22, 23). The nurses and field interviewers who administered the Geriatric Mental State instrument underwent extensive training by psychiatrists who were certified trainers at the Institute of Mental Health, and they received close field monitoring of diagnostic interviews during the survey. A computer-assisted system, the Automated Geriatric Examination for Computer Assisted Taxonomy (AGECAT) (24), was used to generate five levels of diagnostic confidence for determining "caseness." Diagnostic confidence levels of 3–5 for cases meet full criteria for *Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, diagnoses of dementia, depression, and other disorders.

We excluded from the analysis 77 subjects with dementia, given the possibility that they might report reduced food and

**TABLE 3. Mini-Mental State Examination scores of elderly subjects by curry intake ($n = 1,010$), Singapore National Mental Health Survey, 2003**

| Curry consumption*,† | No. | Unadjusted‡ | | Adjusted§ | |
|---|---|---|---|---|---|
| | | Mean score | 95% confidence interval | Mean score | 95% confidence interval |
| Overall | | | | | |
| Never or rarely | 163 | 24.9 | 24.2, 25.7 | 23.3 | 21.2, 25.4 |
| Occasionally | 411 | 26.2 | 25.8, 26.6 | 24.8 | 22.9, 26.7 |
| Often | 436 | 26.0 | 25.6, 26.4 | 24.8 | 22.9, 26.6 |
| ANOVA¶ | | | $p = 0.004$ | | $p = 0.023$ |
| Men | | | | | |
| Never or rarely | 76 | 26.0 | 24.9, 27.1 | 23.1 | 20.8, 25.4 |
| Occasionally | 185 | 27.7 | 27.3, 28.1 | 24.3 | 22.0, 26.6 |
| Often | 217 | 27.5 | 27.1, 27.9 | 24.6 | 22.3, 26.9 |
| ANOVA | | | $p = 0.001$ | | $p = 0.002$ |
| Women | | | | | |
| Never or rarely | 87 | 24.0 | 22.9, 25.0 | 25.0 | 21.6, 28.5 |
| Occasionally | 226 | 24.9 | 24.4, 25.5 | 25.7 | 22.3, 29.1 |
| Often | 219 | 24.6 | 24.0, 25.2 | 25.5 | 22.1, 28.8 |
| ANOVA | | | $p = 0.24$ | | $p = 0.40$ |
| Chinese ethnicity | | | | | |
| Never or rarely | 112 | 25.8 | 25.0, 26.7 | 27.6 | 25.1, 30.1 |
| Occasionally | 261 | 26.9 | 26.5, 27.3 | 28.2 | 25.7, 30.8 |
| Often | 103 | 27.0 | 26.4, 27.6 | 27.8 | 25.3, 30.3 |
| ANOVA | | | $p = 0.016$ | | $p = 0.112$ |
| Malay ethnicity | | | | | |
| Never or rarely | 45 | 22.8 | 21.3, 24.4 | 21.7 | 16.1, 27.3 |
| Occasionally | 114 | 24.7 | 23.8, 25.6 | 22.6 | 17.0, 28.2 |
| Often | 159 | 25.4 | 24.6, 26.1 | 23.3 | 17.7, 28.9 |
| ANOVA | | | $p = 0.007$ | | $p = 0.065$ |
| Indian ethnicity | | | | | |
| Never or rarely | 6 | 24.3 | 17.3, 31.4 | 21.6 | 16.6, 26.6 |
| Occasionally | 36 | 25.9 | 24.4, 27.3 | 24.5 | 20.6, 28.4 |
| Often | 174 | 26.1 | 25.5, 26.7 | 24.1 | 20.4, 27.9 |
| ANOVA | | | $p = 0.59$ | | $p = 0.021$ |

**Table continues**

nutritional intakes because of their condition, and another five subjects who were unable to perform the MMSE because of stroke and dysphasia.

Statistical analyses performed on 1,010 nondemented subjects used one-way analysis of variance for significance testing. We used weighted generalized linear modeling of MMSE scores on three categories of curry consumption, with polynomial contrast of linear and quadratic effects across categories, and estimated the adjusted mean total MMSE score for the curry consumption groups, with covariate adjustment for gender, age, educational level, ethnicity, hypertension, dsylipidemia, coronary artery disease, stroke, diabetes, asthma, chronic obstructive pulmonary disease, smoking, alcohol, NSAID and steroid use, basic and instrumental activities of daily living (ADL), fitness, social and productive activities, and depression. The variables in the model were dichotomized for age (<75, ≥75 years), alcohol use (≥1 drink daily or less), smoking (ever smoker and never smoker), and the presence of cardiovascular disease and its risk factors and depression (yes, no). Polychotomized variables included education in three levels (no education, 1–6 years, and >6 years), NSAID use (none, occasionally, frequently), and the summed scores for fitness and social and productive activities that were categorized in ordinal variables as tertiles. Basic and instrumental ADL variables were combined in a hierarchical classification of functional disability in three levels: 1) ''ADL disabled'' if they had any disability in ADL, 2) ''instrumental ADL disabled'' if they had no ADL disability but had any disability in instrumental ADL, and

**TABLE 3. Continued**

| Curry consumption*,† | No. | Unadjusted‡ | | Adjusted§ | |
|---|---|---|---|---|---|
| | | Mean score | 95% confidence interval | Mean score | 95% confidence interval |
| Age <75 years | | | | | |
| Never or rarely | 108 | 25.4 | 24.5, 26.2 | 25.0 | 22.7, 27.3 |
| Occasionally | 328 | 26.5 | 26.1, 26.9 | 25.9 | 23.6, 28.2 |
| Often | 368 | 26.4 | 26.0, 26.8 | 26.0 | 23.7, 28.2 |
| ANOVA | | | $p = 0.029$ | | $p = 0.036$ |
| Age ≥75 years | | | | | |
| Never or rarely | 55 | 24.1 | 22.6, 25.6 | 21.9 | 17.7, 26.1 |
| Occasionally | 83 | 25.0 | 24.9, 26.0 | 22.4 | 18.4, 26.5 |
| Often | 68 | 24.2 | 23.0, 25.4 | 22.6 | 18.6, 26.7 |
| ANOVA | | | $p = 0.49$ | | $p = 0.64$ |
| Education | | | | | |
| None | | | | | |
| Never or rarely | 75 | 23.3 | 22.1, 24.6 | 19.9 | 14.7, 25.1 |
| Occasionally | 153 | 24.3 | 23.6, 24.9 | 20.8 | 15.7, 25.9 |
| Often | 120 | 23.1 | 22.3, 24.0 | 21.1 | 15.9, 26.2 |
| ANOVA | | | $p = 0.09$ | | $p = 0.17$ |
| Primary | | | | | |
| Never or rarely | 54 | 25.1 | 23.9, 26.3 | 25.7 | 23.1, 28.3 |
| Occasionally | 174 | 26.7 | 26.2, 27.3 | 26.8 | 24.2, 29.3 |
| Often | 189 | 26.3 | 25.8, 26.9 | 27.1 | 24.6, 29.6 |
| ANOVA | | | $p = 0.020$ | | $p = 0.037$ |
| Secondary | | | | | |
| Never or rarely | 34 | 28.1 | 27.1, 29.2 | 25.2 | 21.5, 28.8 |
| Occasionally | 84 | 28.5 | 28.0, 29.1 | 25.5 | 22.0, 29.1 |
| Often | 127 | 28.3 | 27.9, 28.8 | 25.5 | 22.0, 28.9 |
| ANOVA | | | $p = 0.70$ | | $p = 0.77$ |

* Never or rarely (less than once in 6 months); occasionally (more than or once in 6 months but less than once a month); often (once a month or more, weekly, or daily).

† Interactions: gender × curry: $F = 0.422$, 2 df, $p = 0.66$; ethnicity × curry: $F = 2.221$, 4 df, $p = 0.065$; age × curry: $F = 0.102$, 2 df, $p = 0.90$; education × curry: $F = 0.327$, 4 df, $p = 0.86$.

‡ Unweighted sample estimates.

§ Weighted least-squares regression estimates adjusted for age, education, gender, ethnicity, hypertension, dyslipidemia, diabetes, coronary artery disease, stroke, asthma, chronic obstructive pulmonary disease, visual and hearing impairments, depression, nonsteroidal antiinflammatory drug use, oral steroid use, smoking, alcohol, functional disability, fitness, and social and productive activities.

¶ ANOVA, analysis of variance.

3) ''no ADL or instrumental ADL disability.'' All $p$ values of statistical significance were two tailed. Statistical analyses were performed using SPSS, version 13.0, software (SPSS, Inc., Chicago, Illinois).

## RESULTS

The mean age of the subjects was 68.9 years (range: 60–93 years); 34.5 percent were without any formal education. The mean MMSE score was 25.9 (standard deviation: 4.22) and the median score, 27.0 (first and third quartiles: 24 and 30). The majority of the subjects consumed curry at least occasionally (once in 6 months), 43 percent consumed curry at least once a month to daily, while only 16 percent of the subjects reported never or rarely consuming curry.

Table 1 shows the distribution of potential sociodemographic, health, and behavioral correlates of MMSE performance among the subjects according to the level of curry consumption. Of note, subjects with occasional or frequent curry consumption included significantly more who were Indian; were better educated; participated in social,

productive, and fitness activities; had diabetes; used NSAIDs; or were smokers.

As shown in table 2, among the potential correlates of cognitive functioning, age, gender, ethnicity (Malay and Indian), educational levels, instrumental/basic ADL dependence, levels of social activities, coronary artery disease, and asthma showed significant independent associations with MMSE performance scores, in expected fashion.

Compared with subjects who had never or rarely consumed curry, subjects with higher levels of curry consumption showed higher crude mean MMSE scores ($p = 0.004$), as well as adjusted mean MMSE scores ($p = 0.023$), when controlled for potential confounding by known and putative correlates of MMSE performance (table 3). The test for linear trends was significant ($p = 0.029$). Pairwise comparisons were statistically significant for ''occasional'' versus ''never or rarely'' and for ''often and very often'' versus ''never or rarely'' curry consumption; the difference between ''occasional'' and ''often and very often'' curry consumption was not statistically significant. In the highest exposure category, the difference in MMSE score between ''often'' ($n = 245$) and ''very often'' ($n = 191$) curry consumption was negligible (crude means of 26.1 and 25.9 and adjusted means of 24.2 and 24.3).

Table 3 also shows subgroup analyses of the relations between MMSE scores and curry consumption. There appeared to be consistent associations of curry consumption with MMSE scores across different subgroups of subjects defined by gender, age, education, and ethnicity, although the results are not statistically significant in some subgroups because of insufficient numbers of subjects. The magnitude of the effect of curry consumption on MMSE scores appeared to be more pronounced in Indians, relative to the effects observed in Chinese or Malays (''effect modification''), but the interaction between ethnicity and curry was of borderline significance ($p = 0.065$).

Similar results of associations of curry consumption with cognitive impairment (defined as MMSE scores of $\leq$23) were obtained from logistic regression estimates of the odds ratio (table 4). The crude odds ratio of association for ''occasional'' curry consumption was 0.62 (95 percent confidence interval (CI): 0.41, 0.92) and for ''often'' curry consumption was 0.65 (95 percent CI: 0.44, 0.97). Adjusted for all potential confounding variables, the odds ratio for ''occasional'' curry consumption was 0.62 (95 percent CI: 0.38, 1.03) and for ''often'' curry consumption was 0.51 (95 percent CI: 0.21, 0.90).

**TABLE 4. Odds ratio of association of curry consumption with cognitive impairment (Mini-Mental State Examination score of $\leq$23), Singapore National Mental Health Survey, 2003**

| Curry consumption* | Crude | | Adjusted† | |
|---|---|---|---|---|
| | Odds ratio | 95% confidence interval | Odds ratio | 95% confidence interval |
| Never/rarely | 1 | | 1 | |
| Occasionally | 0.62 | 0.41, 0.92 | 0.62 | 0.38, 1.03 |
| Often | 0.65 | 0.44, 0.97 | 0.51 | 0.21, 0.90 |

* Never or rarely (less than once in 6 months); occasionally (more than or once in 6 months but less than once a month); often (once a month or more, weekly, or daily).

† Adjusted for age, gender, ethnicity, educational levels, instrumental activities of daily living/basic activities of daily living dependence (hierarchical levels), social activities (three levels), productive activities (three levels), fitness activities (three levels), visual impairment, hearing impairment, hypertension, dyslipidemia, coronary artery disease, congestive heart failure, diabetes, stroke, asthma, chronic obstructive pulmonary disease, depression, frequency of nonsteroidal antiinflammatory drug use, frequency of steroid use, alcohol consumption, smoking, and curry consumption.

## DISCUSSION

These findings provide the first epidemiologic evidence supporting a link between curry consumption and cognitive performance that was suggested by a large volume of earlier experimental evidence. The one-point difference in mean MMSE scores between the curry exposure groups was not trivial, considering that it was equivalent to a 10-year age-incremental effect based on regression estimates in the multivariate analysis. However, more detailed neuropsychological studies are called for to define the specific neuropsychological functions that are modified.

It is especially worth noting that, even with the low and moderate levels of curry consumption reported by the respondents, better cognitive performance was observed. The statistically significant linear trend of association also supports a dose-response relation. However, it would also appear equally likely that higher levels of curry consumption were not associated with increasingly better cognitive performance, given the lack of statistical significance in difference between the ''occasional'' and ''often'' curry consumption groups. This would also be consistent with the reported experimental evidence that low, but not high, doses of curcumin reduced β-amyloid and plaque burden (14).

Although these results are suggestive of a biologically plausible therapeutic effect, we emphasize that they do not establish a clear and direct causal effect of curry consumption on improving cognitive function. The results from cross-sectional data analysis should be interpreted with caution. It is possible that subjects with dementia or severe cognitive impairment may reduce their food intake and curry intake at the same time. To prevent demonstrating such a spurious relation, we took the precaution to exclude these subjects in the study. There are also no good reasons to believe that subjects with better cognitive function would be particularly predisposed to consume more curry.

We have not determined the accuracy of the self-reported levels of curry consumption in any prior validation study but surmise that any reporting inaccuracy would more likely than not result in exposure misclassification bias toward the null hypothesis. Curry is the predominant dietary source of turmeric intake in this population. Although we attempted to measure the consumption of turmeric-rich curry specifically, it is possible that some actual consumption may not have been identified because it was masked by other accompanying spices. Other sources of turmeric intake are considered to be less frequent. Turmeric is better known as ''yellow ginger'' among the Chinese and, less frequently,

may be consumed as a beverage in itself or added in tea or dessert soup. These were not elicited in the questionnaire. As with many other ''nutraceutical'' agents, specific formulations of curcumin and turmeric have appeared on the shelves in retail outlets, but we have information in another study that consumption is very infrequent.

Yellow curry content may differ in foods consumed by different ethnicities; for the same frequency of consumption, Indian curried foods may contain more turmeric. This is consistent with the suggestion of effect modification of curry consumption by ethnicity in the data ($p = 0.065$); for the same frequency level of curry consumption, the effects on MMSE scores seem to be more pronounced in Indians than in Chinese or Malay. Added to the fact that Indians consume curry much more frequently than other ethnic groups do, there is little doubt about the higher level of turmeric consumption among them. Unfortunately among Indians, other cardiovascular risk factors and cardiovascular diseases are known to be so much more prevalent among them, but overall their cognitive functioning status was actually lower than that of Chinese (Malays are just as low). Nevertheless, these observations also suggest that the potential cognitive enhancing effect of curry (if any) is feasible in subjects with lowered cognitive functioning due to other causes.

Alternative explanations for the observed association may lie in confounding by known and potential correlates of MMSE performance, such as sociodemographic variables (age, education, gender, ethnicity), health conditions and medications (hypertension, dyslipidemia, diabetes, cardiovascular disease, stroke, asthma, chronic obstructive pulmonary disease, visual and hearing impairments, depression, NSAID use, oral steroid use), and health behaviors (smoking, alcohol, functional disability, fitness, social and productive activities). In multivariate analyses, we found no evidence that better cognitive function in subjects who consume curry was explained by more favorable risk factor profiles.

However, it is possible that the results could be confounded by other dietary factors, such as vegetable intake or fat intake, which occur with curry consumption. In addition, the level of curry consumption may be correlated with total energy intake, and it would be desirable to adjust for this. Unfortunately, the present study did not include detailed measures of dietary fat, vegetable intake, or total caloric intake. Future studies should consider these measures as possible confounding factors. Elsewhere, we had data available to qualitatively examine whether the association may be confounded by other known dietary determinants for cognitive function, by examining the relation between curry consumption and serum levels of lipids, folate, vitamin $B_{12}$, and homocysteine. In a whole-area population survey of residents in the southeast region of Singapore (Singapore Longitudinal Aging Study), data are being collected by use of identical questions on curry consumption and by standard laboratory measurements of fasting serum levels of triglycerides and cholesterol, folate, vitamin $B_{12}$, and homocysteine, on community-living older adults aged 55 or more years ($n = 674$; response rate, 85 percent). These preliminary results indicate that the level of curry consumption was not related to serum levels of triglycerides (Spearman's rho = 0.03, $p = 0.41$), total cholesterol (Spearman's rho = −0.02, $p = 0.65$), low density lipoprotein cholesterol (Spearman's rho = −0.01, $p = 0.69$), high density lipoprotein cholesterol (Spearman's rho = −0.03, $p = 0.44$), folate (Spearman's rho = 0.05, $p = 0.21$), vitamin $B_{12}$ (Spearman's rho = 0.02, $p = 0.62$), or homocysteine (Spearman's rho = 0.05, $p = 0.23$), suggesting that confounding by dietary fat, folate, or vitamin $B_{12}$ is not likely.

Turmeric, the dried rhizome powder from which curcumin is extracted, is the principal ingredient of curry that is consumed by millions of people. Turmeric is most widely consumed by people in the Indian subcontinent and the Indo-China archipelago. Interestingly, it has also been purported that the prevalence of Alzheimer's disease in India among elderly between 70 and 79 years of age is fourfold less than that of the United States (25). Elsewhere in the world, curry is consumed much less frequently and in smaller amounts by other ethnic populations. The results reported here are therefore significant, as they point to a significant beneficial effect on cognitive functioning with even low-to-moderate levels of curry consumption.

In conclusion, we report tentative evidence of an observed association between curry consumption and better cognitive function in elderly Asian subjects. More firm evidence may come from further investigations of curry consumption in relation to Alzheimer's disease in longitudinally followed up cohorts of elderly persons and from investigations that further characterize the specific neurocognitive functions that are enhanced by turmeric.

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