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A study of the association between cognitive abilities and dietary intake in young women

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Running title: Cognition and nutrition

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Abstract

Background: Cognitive abilities comprise activities that relate to receiving and responding to information from the environment, internal processing, making complex decisions and then responding to this in the context of behavior.

Aim: The current study investigated the association between dietary intake and seven aspects of cognitive abilities among healthy, young women.

Methods: The study was carried out among 182 women aged 18–25 years. A valid and reliable food frequency questionnaire (FFQ) containing 65 food items was used to estimate dietary intake. Neuropsychological function and cognitive abilities of participants were determined using standard questionnaires.

Result: Significant differences were found in depression, anxiety, stress, physical and mental health-related quality of life as well as day time sleepiness for the participants in different quartiles of cognitive abilities score (p<0.05). Participants in the fourth quartile of cognitive abilities score consumed significantly higher energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin compared to those in the lowest quartile (p<0.05). There were strong correlations between total cognitive abilities score and dietary sodium, calcium, phosphorus and thiamin (p<0.05). Using stepwise multiple linear regression analysis, iron and thiamin were statistically significant factors for the prediction of cognitive abilities.

Conclusion: These findings demonstrate that neurocognitive function is related to dietary macro and micronutrients including energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin on cognitive performance among young woman without memory deficit.

Keywords: Insomnia; depression; iron; Thiamin; cognition
1. Introduction

Cognitive ability (i.e. executive function, processing speed, verbal learning and memory, and attention) is essential for functioning in daily life, and are involved in making intricate decisions (Bishop et al., 2018). Cognitive decline comprises: reduced concentration and attention, poor learning, memory impairment which negatively affected quality of life of individuals and their families (Richards and Deary, 2005; Batty et al., 2007). Therefore, the determination of health factors, such as environmental factors and lifestyle behaviors– that is related to cognitive performance, has significant implications for cognitive health across the life course.

Several lines of evidence indicate associations between diet and cognitive abilities in later years (Crichton et al., 2015). Longitudinal studies have reported relationships between specific nutrients or dietary patterns and brain-volume (Hooshmand et al., 2016; Luciano et al., 2017) and brain integrity (Virtanen et al., 2013), with results from several clinical trials that support these findings (Smith et al., 2010; Witte et al., 2014). It has been shown that an inadequate dietary intake of essential micronutrients such as vitamins and minerals may have adverse consequences on brain function and cognitive ability (Prado and Dewey, 2014). Studies investigating the relationships between cognition and diet have mainly concentrated on diet as a predictor of cognitive status in later life.

Dietary modification is one potential approach to preventing, or slowing cognitive impairment. The majority of previous research has focused on middle aged and elderly populations who also have other potential age-associated factors that affect cognition. So, the relationship between dietary intake and cognition in younger, healthier adults is unclear. On the other hand, a major issue in maintaining cognitive health is the most appropriate time for any intervention. Intellectual variations in adults may be attributable to factors in childhood (Deary et al., 2004), and older-age cognition may itself be initiated in early adulthood.
(Salthouse, 2009). For example the pathology associated with the development of dementia develops over many years before the appearance of clinical symptoms (Sperling et al., 2011). Thus, the effects of diet on cognitive ageing is likely to be affected by intake over the lifetime (Benton, 2010). Hence, the best time for intervention to prevent cognitive impairment in later life is during childhood and adolescence.

On the other hand, cognitive decline has been associated with multiple factors in addition to diet, such as depression, anxiety, and sleep problems (Arfken et al., 1999; Merlino et al., 2010). There is accumulating evidence that impaired cognitive ability is a possible predictor of several psychiatric complications, including depression (Der et al., 2009; Koenen et al., 2009), or one of its associated symptoms such as suicide completion (Fergusson et al., 2005), and suicidal ideation (Gunnell et al., 2009). Moreover, specific sleep disturbances have been found to have adverse effects on attention, learning, memory, academic performance and processing ability in several areas of cognitive functioning, and may further be related to behavioral/psychological maladjustment and lower quality of life (Ohayon and Vecchierini, 2002; Buckhalt and Staton, 2011).

There have been few previous studies of cognition research in young adults. The current study aimed to investigate the association between dietary intake and seven aspects of cognitive function, including: memory, inhibitory control and selective attention, decision making, planning, sustained attention, social cognition and cognitive flexibility among healthy, young women. A secondary aim was to explore the association between cognitive performance and symptoms of depression, anxiety and sleep disturbance in this population.

2. Methods

2.1. Study design
This cross-sectional study was conducted in Birjand, South Khorasan, Iran, during January 2020. The total population sample in this study comprised 182 healthy young females who were recruited from 5 different universities in Birjand. Since, we wanted to perform our investigation on a homogeneous population in order to control for confounders, so only unmarried females aged between 18-25 y were included. Exclusion criteria were having any acute or chronic disease, or a past medical history of any psychological disorders such as depression and aggression. The Ethical Committee of Birjanad University of Medical Sciences approved the study protocol (Code: 5243), and informed written consent was obtained from all participants.

2.2. Measurements

2.2.1. Cognitive Abilities

The Cognitive Abilities Questionnaire (CAQ) is a valid and reliable tool which measured cognitive performance in 7 distinctive dimensions, that included: memory, inhibitory control and selective attention, decision making, planning, sustained attention, social cognition and cognitive flexibility (Nejati, 2013). This instrument comprised 30 items rated on a five-point Likert scale (1–5) to provide a total score from 30 to 150. Higher scores reflected better cognition functions.

2.2.2. Psychological variables and sleep pattern

Depression, anxiety and stress assessment: Depression Anxiety and Stress Scale (DASS-21) is a valid and reliable tool to assess status of negative well-beings (Henry and Crawford, 2005). This questionnaire includes 21-items with 3 subscales (each have 7 questions) with 4-Likert scale scored 0-3 to measuring severity of depression, anxiety and stress. Since the DAS-21 is the brief version of DAS-42; the final score of each subclass were doubled. A higher score reflects poorer emotional responses. The Persian version of the DASS-21 has been widely previously validated and shows good test-retest reliability (Sahebi et al., 2005).
**Insomnia status:** The Insomnia Severity Index (ISI) is a self-report questionnaire evaluating the nature, intensity, and consequence of insomnia. This tool computes severity of sleep initiation, sleep maintenance, and timely morning awakening complications, degree of sleep satisfaction and interfering of sleep difficulties with daytime activities. It includes 7 items with five-point Likert scale rated from 0 (minor problem) to 4 (maximum problem), providing a total score range from 0 to 28 (Yazdi et al., 2012).

**Sleepiness status:** The Epworth Sleepiness Scale (ESS) is a questionnaire that comprises 8 items on a 4-point Likert scale (0-3), assessing the intensity of sleepiness in the past two weeks. The total score ranges from 0 to 24, with a higher score suggesting a greater probability of falling asleep under routine conditions of daily living (Haghighi et al., 2013).

2.2.3. **Quality of life**
Health-related quality of life was quantified using the SF-12. This tool has been observed to be a reliable and valid measure of both physical- and mental-related health status in different population (Ware et al., 2002). The SF-12 is a brief version of the SF-36, that is widely used questionnaire, which consists of 12 questions covering 8 health domains. The Persian version of this tool has proven reliability and validity (Montazeri et al., 2009).

2.2.4. **Demographic and anthropometric parameters**
The demographic and anthropometric parameters including age, height, weight, waist and hip circumference, systolic blood pressure and diastolic blood pressure were obtained in a Health Center, by an expert nurse using standard protocols. Weight was measured wearing the least clothes and without shoes by a Seca digital scale. The height was certain by using a fixed measuring tape on the wall on standing position without shoes. Body mass index (BMI) was calculated as weight (kg)/height $^2$(m). Waist circumference was assessed using a flexible tape measure from the narrowest point between the lowest rib and the iliac crest. Waist-to-hip
ratio (WHR) was obtained via dividing waist circumference: hip circumference. Hip circumferences were measured at the level of the anterior superior iliac spine, where this could be felt, in a different way at the broadest circumference below the waist.

The systolic blood pressure and diastolic blood pressure were measured using the left arm after 15 minutes rest by sphygmomanometer twice in the same manner. The mean of two recorded measurements was considered as the participant’s blood pressure. If the two measurements differ higher than 15 mm Hg in diastolic or 25 mm Hg in systolic blood pressure, the third measurement was taken and the two closest measurements were averaged.

2.2.5. Dietary intake

A valid and reliable semi quantitative food frequency questionnaire (FFQ) containing 65 food items was administered by trained interviewers to estimate dietary intakes of the study participants over the previous year (Ahmadnezhad et al., 2017; Asadi et al., 2019). For each food item, 5 frequency consumption groups (per day, week, month, rarely, and never) and portion size. Nutrient intakes of each individuals, was calculated using the US Department of Agriculture’s national nutrient databank (Pehrsson et al., 2000).

2.3. Statistical analysis

Participants were categorized into quartiles for cognitive ability scores. One-way analysis of variance (ANOVA) was used to evaluate significant differences in continuous variables including scores of depression, stress, quality of life, insomnia and sleepiness as well as dietary intakes across quartiles of cognitive abilities score. Pearson correlation coefficient was used to assess the relationship between dietary intake and cognitive abilities task. Stepwise multiple linear regression was used to assess the association between dietary intakes and quartiles of cognitive abilities score. In the adjusted model, we controlled for potential
confounders including age, energy intake and BMI. A p-value less than 0.05 was set as statistically significant.

3. Results

The mean ± SD of age and BMI of the participants was 20.8±1.7 years and 20.8±2.9 kg/m², respectively. The mean±SD of cognitive abilities score of participants was 111.9±14.1 (range 69-143).

Demographic, anthropometric, clinical and psychological characteristics of individuals by quartile of cognitive ability score are shown in Table 1. Significant differences were found in depression (p<0.001), anxiety (p<0.001), stress (p<0.001), physical (p=0.009) and mental (p<0.001) health-related quality of life as well as day time sleepiness (p<0.001) for the participants in different quartiles of cognitive abilities score. There were no significant differences in demographic characteristics and anthropometric parameters across quartiles of cognitive abilities score (p>0.05).

The dietary intakes of participants across quartiles of cognitive abilities score are shown in Table 2. Subjects in the 4th quartile of cognitive ability scores had a significantly higher intake of dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin intake compared with those lowest quartile (p<0.05).

Among different cognitive ability tasks, social cognition significantly correlated with dietary energy (r=0.15; p=0.04), carbohydrate (r=0.18; p=0.01), protein (r=0.18; p=0.02), calcium (r=0.14; p=0.049), phosphorous (r=0.28; p=0.007), manganese (r=0.27; p<0.001), iron (r=0.21; p=0.005), zinc (r=0.19; p=0.01), vitamin A (r=0.21; p=0.005), thiamin (r=0.23; p=0.002) and riboflavin (r=0.23; p=0.002) (Table 3). There were strong correlations between total
cognitive ability scores and dietary sodium (r=0.17; p=0.02), calcium (r=0.21; p=0.006), phosphorus (r=0.15; p=0.04) and thiamin (r=0.19; p=0.012).

Collinearity analysis demonstrated that there were obvious multi-collinearities among variables. Using a stepwise multiple linear regression analysis, dietary iron and thiamin were statistically significant factors (Table 4).

**Discussion:**

Nutrition is an important lifestyle factor that can influence the risk of future cognitive decline. To our knowledge, this study is the first to show that dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin and riboflavin are all associated with cognitive performance in young women.

One potential explanation is that glucose intake may enhance memory by increasing plasma glucose levels, affecting glucose uptake in the brain and an elevation in glucose-induced production of acetylcholine in the hippocampus region (Wenk, 1989). Others have hypothesized that the insulin response to an elevation in glucose may impact on memory (Craft et al., 1999). There is accumulating evidence indicating that glucose regulation is associated with cognitive performance (Kaplan et al., 2000). Dietary glucose drink increase cognition in individuals with poor memories or β cell function independent of blood glucose (Kaplan et al., 2000; Korol and Gold, 1998; Manning et al., 1997). Older adults with type 2 diabetes develop lower scores on memory tests compared to age-matched normal controls (Strachan et al., 1997), and non-diabetic cases with poor glucose regulation had poorer cognition versus those with superior regulation (Messier et al., 1999; Messier et al., 1997).

Importantly, in a study among healthy elderly subjects, ingestion of macronutrients (carbohydrate, protein, and fat) all improved memory 15 minute after administration.
Interesting, results showed that the ingestion of energy, in the absence of raised blood glucose, can also enhance memory (Kaplan et al., 2001). In an observational study among elderly people (>70 years), a low intake proteins was related with higher risk of mild cognitive impairment and dementia (Roberts et al., 2012). Notably, ingestion of energy can give rise to better memory performance independent of elevations in blood glucose that does not rely on the acetylcholine or insulin theory, but rather indicates that macronutrients may influence cognition through more than one pathway.

Among the different cognitive ability tasks, social cognition was significantly associated with dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin and riboflavin. One aspect of cognition which is noteworthy for investigation is social cognition. Social cognition is the complex processing of social information for adaptive performance (Ochsner and Lieberman, 2001). It refers to a complex set of higher-order neuropsychological domains which supported adaptive behaviors in reaction to others (Amodio and Frith, 2016).

The results of a systematic review evaluating 8 cross-sectional and 13 longitudinal surveys, did not support the view that a high dietary antioxidant content is related to better cognitive performance or a reduced risk of dementia (Crichton et al., 2013).

In the present study, higher calcium intake predicted better cognitive abilities. Other studies have reported a significant relationship between calcium intake and lower risk of dementia and higher cognitive performances (Ozawa et al., 2012; Velho et al., 2008). Notably, in a large study among 16,948 Chinese populations, dairy calcium was associated with reduced risk, whereas non-dairy calcium did not affect the risk of cognitive decline (Talaei et al., 2019). In our study, the dietary intake of calcium and phosphorus was positively associated with cognitive flexibility. Cognitive flexibility is defined as the competence to actively shift
attention, choose information, and change response strategy in response to altering task demands (Davidson et al., 2006; Kane and Engle, 2002).

Several previous studies have reported that a lower intake of iron was associated with reduced cognitive abilities (Quintas et al., 1997; Cook et al., 1994). Positive changes in Raven’s Coloured Progressive Matrices (RCPM) test score gains were also predicted by daily the available iron intake (Gewa et al., 2009). Animal studies have found that brain iron is sensitive to dietary iron (Prasad et al., 2005; Pinero et al., 2000). Iron treatment positively increased concentration and intelligence quotient in humans (Bruner et al., 1996; Seshadri and Gopaldas, 1989). Our result reinforces the significance of dietary iron in promoting cognitive function in young women.

A study among Korean elderly people showed that female cases with lower cognitive abilities had significantly lower intake of energy, protein, fat, carbohydrate, calcium, phosphorous, iron, vitamin A, thiamin, and riboflavin versus those with normal cognitive performance (Lee et al., 2001). Zinc is a cofactor for proteins or enzymes with anti-oxidative action. The brain has a high susceptibility to oxidative damage, and it has been speculated that oxidative stress or insufficient antioxidant defense might coordinate the pathogenesis and progression of cognitive impairments (Mecocci et al., 2018). Furthermore, Gewa et al reported that zinc intake was significantly related to increased digit span-total test scores over time; whereas riboflavin intakes were linked with significantly higher digit span-forward test scores over time (Gewa et al., 2009).

Epidemiological studies have demonstrated that dementia and cognitive decline are correlated with lower intakes of B vitamins (Gillette-Guyonnet et al., 2007). B-group vitamins affect cognitive performance and development by implicating in neurotransmitter generation and modulation, integration of axon and myelin sheath as well as homocysteine metabolism (Haller, 2005). It has been reported that even moderately increased (within the normal range)
levels of homocysteine might be related with higher risk of dementia in people older (Smith et al., 2010). Thiamine-dependent enzymes including transketolase, pyruvate dehydrogenase, α-ketoglutarate dehydrogenase, and branched chain α-ketoacid dehydrogenase participated in glycolysis and the Krebs cycle, and shortage in the function of these enzymes may involve in decreased glucose metabolism, as showed in the brain of dementia patients (Chen and Zhong, 2013; Gibson et al., 2016).

Another finding of our study was an inverse association between cognitive ability with depression, anxiety, stress, insomnia and sleepiness scores, and a positive association with quality of life. Previously, it has been reported that psychosocial stress affects many cognitive processes (Shields et al., 2016; Allen et al., 2014). Additionally, stress generally weakened long-term memory retrieval or working memory (Shields et al., 2016; Schoofs et al., 2013).

There are several limitations to this study. Due to the nature of cross-sectional design, our results do not indicate causal relationships and therefore validation is required in longitudinal analyses. Use of self-reported dietary intake by FFQ and self-reported measures of cognition was another limitation which may confer recall bias.

In summary, our results demonstrate the association between neurocognitive function and dietary macro and micronutrients including energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin on cognitive performance among young woman without memory deficit. It was not clear whether supplementation with these micro and micronutrients could promote cognitive abilities among healthy youngers. So, future studies should explore whether dietary interventions can prevent cognitive decline in healthy adults.
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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards
Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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Ethics approval: Ethical approval was obtained from the Ethnic committee of Birjand University of Medical Sciences.

Author's contribution
AB contributed to examination, writing, statistical analysis. M.A and S.M. contributed to planning, supervision and correction. MS contributed to recruiting, examination, writing. AA contributed to recruiting, examination, writing. MA and contributed to examination, writing. HR contributed to examination, writing. AT and AAF contributed to statistical analysis, correction. GAF contributed to planning and correction. SK contributed to examination, supervision and edition. ZH contributed to planning, supervision and correction.
References:


<table>
<thead>
<tr>
<th>Variables</th>
<th>Q1 score: 69-103</th>
<th>Q2 score: 103-114</th>
<th>Q3 score: 114-121</th>
<th>Q4 score: 121-143</th>
<th>P value $^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>21.2±1.7</td>
<td>20.8±1.7</td>
<td>20.6±1.2</td>
<td>20.5±2.1</td>
<td>0.25</td>
</tr>
<tr>
<td>BMI (Kg/m2)</td>
<td>20.0±2.8</td>
<td>20.5±2.6</td>
<td>21.2±3.4</td>
<td>21.7±2.3</td>
<td>0.06</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>52.8±7.4</td>
<td>54.8±8.0</td>
<td>55.4±9.4</td>
<td>55.9±6.7</td>
<td>0.39</td>
</tr>
<tr>
<td>WHR</td>
<td>0.72±0.04</td>
<td>0.74±0.04</td>
<td>0.73±0.05</td>
<td>0.74±0.05</td>
<td>0.40</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>10.6±0.9</td>
<td>10.5±1.0</td>
<td>10.6±0.9</td>
<td>10.8±1.1</td>
<td>0.52</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>7.2±0.7</td>
<td>7.0±0.9</td>
<td>7.0±0.6</td>
<td>7.0±0.8</td>
<td>0.69</td>
</tr>
<tr>
<td><strong>Dass-21</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>16.7±9.7</td>
<td>13.5±8.9</td>
<td>8.0±6.6</td>
<td>5.5±5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Anxiety</td>
<td>12.8±7.2</td>
<td>8.9±5.5</td>
<td>8.5±5.8</td>
<td>5.2±4.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stress</td>
<td>24.3±9.5</td>
<td>18.5±8.7</td>
<td>15.5±8.8</td>
<td>10.9±7.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Quality of life (SF-12)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical health</td>
<td>14.9±2.5</td>
<td>15.5±2.7</td>
<td>16.5±2.1</td>
<td>16.1±2.4</td>
<td>0.009</td>
</tr>
<tr>
<td>Mental health</td>
<td>14.7±3.3</td>
<td>16.4±3.9</td>
<td>16.3±3.5</td>
<td>18.3±3.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SF-12 score</td>
<td>29.5±4.7</td>
<td>32.2±5.3</td>
<td>32.9±5.2</td>
<td>34.5±4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Test of sleep pattern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insomnia score (ISI)</td>
<td>6.8±7.5</td>
<td>7.4±6.9</td>
<td>4.6±5.8</td>
<td>5.8±6.9</td>
<td>0.19</td>
</tr>
<tr>
<td>Daytime sleepiness score (ESS)</td>
<td>9.3±6.5</td>
<td>6.5±5.9</td>
<td>4.9±5.4</td>
<td>4.5±4.5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Abbreviations**: Body mass index (BMI); systolic blood pressure (SBP); and diastolic blood pressure (DBP); Waist-to-hip ratio (WHR).

Data presented as Mean±SD.

$^a$ p-value from analysis of the variance (ANOVA) for groups comparison.
Table 2. Dietary intakes of study participants across quarters of cognitive abilities score.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Q1 (n=45)</th>
<th>Q2 (n=49)</th>
<th>Q3 (n=45)</th>
<th>Q4 (n=43)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macronutrient</strong> (per 1000 kcal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>54.2±31.0</td>
<td>60.9±32.7</td>
<td>65.4±26.2</td>
<td>69.3±37.5</td>
<td><strong>0.038</strong></td>
</tr>
<tr>
<td>Protein (g)</td>
<td>28.6±14.0</td>
<td>31.8±13.5</td>
<td>31.1±15.1</td>
<td>37.1±18.5</td>
<td><strong>0.10</strong></td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>17.7±13.2</td>
<td>13.8±9.4</td>
<td>16.6±11.8</td>
<td>11.1±12.1</td>
<td>0.24</td>
</tr>
<tr>
<td>dietary fiber (g)</td>
<td>6.9±2.8</td>
<td>7.0±3.1</td>
<td>7.2±4.3</td>
<td>6.0±3.4</td>
<td>0.44</td>
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<tr>
<td><strong>Antioxidants</strong> (per 1000 kcal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carotene (mcg)</td>
<td>734±370</td>
<td>707±357</td>
<td>765±395</td>
<td>692±400</td>
<td>0.84</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>18.6±15.5</td>
<td>21.3±25.4</td>
<td>18.1±21.8</td>
<td>31.5±49.5</td>
<td>0.64</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>59.3±45.6</td>
<td>62.3±61.3</td>
<td>65.9±52.8</td>
<td>54.9±49.0</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Minerals</strong> (per 1000 kcal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>779±302</td>
<td>801±348</td>
<td>900±965</td>
<td>654±405</td>
<td>0.33</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>207±139</td>
<td>210±119</td>
<td>232±131</td>
<td>258±155</td>
<td><strong>0.037</strong></td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>427±170</td>
<td>377±172</td>
<td>425±223</td>
<td>441±189.6</td>
<td>0.50</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>99.1±41.6</td>
<td>100.5±40.2</td>
<td>111.4±100.1</td>
<td>85.8±37.8</td>
<td>0.35</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>1.32±0.66</td>
<td>1.44±0.81</td>
<td>1.48±0.68</td>
<td>1.46±1.29</td>
<td>0.72</td>
</tr>
<tr>
<td>Selenium (mcg)</td>
<td>26.1±13.8</td>
<td>21.6±10.3</td>
<td>21.2±9.5</td>
<td>20.0±10.8</td>
<td>0.09</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>2.88±1.43</td>
<td>3.33±1.28</td>
<td>3.39±1.81</td>
<td>3.63±1.20</td>
<td><strong>0.035</strong></td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>2.18±1.06</td>
<td>2.48±1.12</td>
<td>2.41±1.35</td>
<td>2.83±1.39</td>
<td><strong>0.047</strong></td>
</tr>
<tr>
<td><strong>Vitamins</strong> (per 1000 kcal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>31.2±38.1</td>
<td>41.3±40.2</td>
<td>53.7±69.1</td>
<td>57.9±64.8</td>
<td><strong>0.044</strong></td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>0.33±0.17</td>
<td>0.39±0.18</td>
<td>0.39±0.25</td>
<td>0.64±0.22</td>
<td><strong>0.031</strong></td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>0.54±0.22</td>
<td>0.62±0.22</td>
<td>0.61±0.31</td>
<td>0.85±0.25</td>
<td><strong>0.049</strong></td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>6.9±3.4</td>
<td>7.9±3.2</td>
<td>8.1±5.8</td>
<td>9.7±5.4</td>
<td><strong>0.041</strong></td>
</tr>
</tbody>
</table>

Data presented as Mean±SD and adjusted for energy intake.
By using analysis of the variance (ANOVA).
Table 3. Pearson correlation coefficient between dietary intake and cognitive abilities task.

<table>
<thead>
<tr>
<th></th>
<th>Memory</th>
<th>Inhibitory control and selective attention</th>
<th>Decision making</th>
<th>Planning</th>
<th>Sustain attention</th>
<th>Social cognition</th>
<th>Cognitive flexibility</th>
<th>Total cognitive ability task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>0.06</td>
<td>0.07</td>
<td>0.09</td>
<td>0.004</td>
<td>-0.05</td>
<td>0.15*</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>0.05</td>
<td>0.03</td>
<td>0.07</td>
<td>0.07</td>
<td>-0.08</td>
<td>0.18*</td>
<td>0.21</td>
<td>0.09</td>
</tr>
<tr>
<td>Protein</td>
<td>0.08</td>
<td>0.04</td>
<td>0.06</td>
<td>0.06</td>
<td>-0.06</td>
<td>0.18*</td>
<td>0.10</td>
<td>0.9</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.15*</td>
<td>0.16*</td>
<td>0.15*</td>
<td>0.12</td>
<td>0.003</td>
<td>0.14*</td>
<td>0.19**</td>
<td>0.21**</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.12</td>
<td>0.09</td>
<td>0.10</td>
<td>0.09</td>
<td>-0.03</td>
<td>0.28**</td>
<td>0.15*</td>
<td>0.15*</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.06</td>
<td>0.05</td>
<td>0.07</td>
<td>0.09</td>
<td>0.004</td>
<td>0.27***</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>Iron</td>
<td>0.08</td>
<td>-0.006</td>
<td>0.02</td>
<td>0.04</td>
<td>-0.07</td>
<td>0.21**</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.11</td>
<td>0.06</td>
<td>0.08</td>
<td>0.08</td>
<td>-0.05</td>
<td>0.19**</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td>0.07</td>
<td>0.01</td>
<td>0.21**</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Thiamin</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.13</td>
<td>0.02</td>
<td>0.23**</td>
<td>0.18*</td>
<td>0.19*</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.07</td>
<td>0.08</td>
<td>0.06</td>
<td>0.08</td>
<td>-0.008</td>
<td>0.23**</td>
<td>0.11</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*P<0.05
**P<0.01
***P<0.001
Table 4. Stepwise multiple linear regression analysis for the effect of independent variables on cognitive abilities score

<table>
<thead>
<tr>
<th>Variables</th>
<th>β</th>
<th>SE</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>137.1</td>
<td>13.5</td>
<td>10.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Energy</td>
<td>0.0001</td>
<td>0.001</td>
<td>-0.56</td>
<td>0.57</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>0.003</td>
<td>0.017</td>
<td>0.16</td>
<td>0.87</td>
</tr>
<tr>
<td>Protein</td>
<td>-0.07</td>
<td>0.11</td>
<td>-0.64</td>
<td>0.52</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.008</td>
<td>0.009</td>
<td>0.94</td>
<td>0.35</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-0.002</td>
<td>0.018</td>
<td>-0.102</td>
<td>0.91</td>
</tr>
<tr>
<td>Manganese</td>
<td>1.00</td>
<td>1.05</td>
<td>0.99</td>
<td>0.34</td>
</tr>
<tr>
<td>Iron</td>
<td>-1.22</td>
<td>0.601</td>
<td>-2.04</td>
<td><strong>0.043</strong></td>
</tr>
<tr>
<td>Zinc</td>
<td>0.38</td>
<td>1.72</td>
<td>0.22</td>
<td>0.82</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>0.005</td>
<td>0.008</td>
<td>0.63</td>
<td>0.53</td>
</tr>
<tr>
<td>Thiamin</td>
<td>7.91</td>
<td>3.99</td>
<td>1.98</td>
<td><strong>0.049</strong></td>
</tr>
<tr>
<td>Riboflavin</td>
<td>-3.82</td>
<td>4.25</td>
<td>-0.901</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Adjusted for age and BMI.