

1 **Low dietary intake of magnesium is associated with increased externalising behaviours in**
2 **adolescents**

3 Lucinda J. Black¹, Karina L. Allen^{1,2}, Peter Jacoby¹, Gina S. Trapp¹, Caroline M. Gallagher¹, Susan
4 M. Byrne², Wendy H. Oddy¹

5 ¹Telethon Kids Institute, The University of Western Australia, Perth, Western Australia; ²School of
6 Psychology, The University of Western Australia, Perth, Western Australia

7

8 **Abstract**

9 **Objective:** Adequate zinc and magnesium intakes may be beneficial for the prevention and
10 treatment of mental health problems, such as depression, anxiety and attention-deficit hyperactivity
11 disorder. We aimed to investigate the prospective association between dietary intakes of zinc and
12 magnesium and internalising and externalising behaviour problems in a population-based cohort of
13 adolescents.

14 **Design:** Prospective analysis (general linear mixed models) of dietary intakes of zinc and
15 magnesium assessed using a validated food frequency questionnaire and mental health symptoms
16 assessed using the Youth Self-Report (YSR), adjusting for sex, physical activity, family income,
17 supplement status, dietary misreporting, BMI, family functioning and energy intake.

18 **Setting:** Western Australian Pregnancy Cohort (Raine) Study.

19 **Subjects:** Adolescents ($n=684$) at the 14 and 17 year follow-ups.

20 **Results:** Higher dietary intake of magnesium (per standard deviation) was significantly associated
21 with reduced externalising behaviours (β -1.45; 95% CI -2.40, -0.50; $p = 0.003$). There was a trend
22 towards reduced externalising behaviours with higher zinc intake (β -0.73; 95% CI -1.57, 0.10; $p =$
23 0.085).

24 **Conclusions:** This study shows an association between higher dietary magnesium intake and
25 reduced externalising behaviour problems in adolescents. We observed a similar trend, although not
26 statistically significant, for zinc intake. Randomised controlled trials are necessary to determine any
27 benefit of micronutrient supplementation in the prevention and treatment of mental health problems
28 in adolescents.

29 Introduction

30

31 Zinc and magnesium are essential minerals involved in functioning of the central nervous system.
32 Dietary sources of zinc include red meat, poultry, legumes, nuts and seeds, certain types of seafood
33 (e.g. oysters, crab and lobster), whole grains, fortified breakfast cereals and dairy products.
34 Magnesium is widely distributed in plant foods, particularly green leafy vegetables, legumes, nuts,
35 seeds and whole grains. Zinc is a co-factor of many enzymes that play a role in brain function⁽¹⁾ and
36 is present in regions of the brain associated with the pathophysiology of mood disorders, including
37 the amygdala, hippocampus and cerebral cortex⁽²⁾. Zinc modulates neuronal excitability by
38 inhibiting both the *gamma*-aminobutyric acid (GABA) and N-methyl-D-aspartate (NMDA)
39 receptors⁽³⁾ and has shown antidepressant-like activities in animal models⁽⁴⁻⁶⁾. Magnesium is another
40 potent antagonist of the NMDA receptor complex⁽⁷⁾ and magnesium deficiency has been related to
41 symptoms such as agitation, anxiety, irritability and hyperexcitability⁽⁸⁾. In rodent models,
42 magnesium depletion increases anxiety and depression-like behaviours^(9, 10), and mice with low
43 erythrocyte magnesium levels have been found to exhibit more aggressive behaviour than those
44 with high magnesium levels⁽¹¹⁾.

45

46 Recently, Jacka and colleagues (2012) reported that dietary intakes of zinc and magnesium were
47 inversely and cross-sectionally associated with depressive and anxiety scores in a population-based
48 sample of women ($n = 1046$)⁽¹²⁾. Other studies have shown inverse relationships between dietary
49 zinc intakes and depression in women⁽¹³⁻¹⁶⁾. Furthermore, research suggests that zinc
50 supplementation as an adjunct to antidepressant drug treatment significantly lowers depressive
51 symptoms in depressed patients compared to antidepressant treatment alone⁽¹⁷⁻¹⁹⁾. Research on
52 magnesium with depressive and anxiety symptoms is less conclusive. Although energy-adjusted
53 magnesium intakes were inversely associated with depression scores in a sample of Norwegian
54 community-dwelling men and women ($n = 5708$)⁽²⁰⁾, this finding was not supported in a cohort ($n =$
55 $12,939$) of Spanish university graduates⁽²¹⁾. Zinc and magnesium supplementation have both been
56 shown to be beneficial in the treatment of attention-deficit hyperactivity disorder (ADHD) in
57 children, as a stand-alone treatment and as an adjunct to medication⁽²²⁻²⁴⁾; however, limited research
58 exists in this area.

59

60 While there is increasing recognition of the role of magnesium and zinc in mental health, most of
61 the evidence to date has focused on adult participants, often with a cross-sectional design or in the
62 context of a clinical trial. In this study, we aimed to examine the prospective association between
63 dietary intakes of zinc and magnesium and internalising (withdrawn, somatic complaints,

64 anxious/depressed) and externalising (attention problems, aggressive/delinquent) behaviour
65 problems in a population-based cohort of adolescents at the 14 and 17 year follow-ups. Our
66 hypothesis was that lower dietary intakes of zinc and magnesium would be associated with
67 increased internalising and externalising behaviour problems.

68

69 **Methods**

70

71 *Participants*

72

73 The Western Australian Pregnancy Cohort (Raine) Study methodology has been described
74 previously⁽²⁵⁾. In brief, a total of 2900 pregnant women attending the public antenatal clinic at King
75 Edward Memorial Hospital, or nearby private practices, were recruited into the Raine Study
76 between May 1989 and November 1991 and gave birth to 2868 children. These children underwent
77 assessment at birth and at regular intervals. Recruitment and all follow-ups were approved by the
78 ethics committees of King Edward Memorial Hospital for Women and the Princess Margaret
79 Hospital for Children, Perth, Western Australia. Informed and written consent was obtained from
80 the participant and/or their primary caregiver for all follow-ups. Data collection for the 14 and 17
81 year follow-ups occurred between 2003-2005 and 2006-2008, respectively.

82

83 *Assessment of mental health*

84

85 Mental health at 14 and 17 years was assessed using the Youth Self Report (YSR), which is a
86 version of the Child Behaviour Checklist for Ages 4-18 (CBCL/4-18) and is designed specifically
87 for self-report in adolescents. The YSR is a 118-item empirically-validated and reliable measure of
88 emotional and behavioural problems in children and adolescents^(26, 27). The YSR generates an
89 externalising problem score that describes uncontrolled and anti-social behaviour (attention
90 problems, aggressive/delinquent) and an internalising problem score that describes over-controlled
91 and inhibited behaviour (withdrawn, somatic complaints, anxious/depressed), with higher scores
92 indicating a higher level of emotional and behavioural problems. We calculated standardised T-
93 scores for total, externalising and internalising problem scales, normalised separately for boys and
94 girls by age.

95

96 *Assessment of zinc and magnesium intakes*

97

98 A semi-quantitative food frequency questionnaire (FFQ) developed by the Commonwealth
99 Scientific and Industrial Research Organisation (CSIRO) in Adelaide, Australia was used to assess
100 zinc and magnesium intakes⁽²⁸⁾. This 212-item FFQ assessed usual dietary intake over the previous
101 year, collecting information on the frequency of consumption of individual foods, mixed dishes and
102 beverages, along with information on usual serving sizes in relation to a standard serving size in
103 household units. Seasonal differences were accounted for by asking how often foods were eaten in
104 summer and winter. At the 14 year follow-up, the primary caregiver was asked to complete the FFQ
105 in association with the adolescent. At the 17 year follow-up, the FFQ was completed by the
106 adolescent. The questionnaire has been validated against a 3-day food record in the same cohort at
107 the 14 year follow-up⁽²⁹⁾.

108

109 All questionnaires were checked by a research nurse and queries were clarified with the adolescent
110 or primary caregiver. Food intake data were entered into a database and verified by CSIRO.
111 Estimated daily micronutrient intakes were provided by CSIRO using nutrient composition derived
112 from four sources: the Australian nutrient database (NUTTAB95)⁽³⁰⁾; the British Food Composition
113 Tables⁽³¹⁾; the US Department of Agriculture food tables; and manufacturers' data. Questionnaires
114 were excluded if the daily energy intake reported was implausible (< 3000 or > 20 000 kJ per day).

115

116 *Potential confounding variables*

117

118 Participants were weighed to the nearest 100 g using a Wedderburn Digital Chair Scale and height
119 was determined to the nearest 0.1 cm with a Holtain Stadiometer. Body Mass Index (BMI) was
120 calculated as weight in kilograms divided by height in metres squared. Dietary misreporting was
121 estimated using the Goldberg method⁽³²⁾, which is widely used to estimate the cut-off levels for
122 under-reporters, plausible reporters and over-reporters in dietary surveys. Current use of nutritional
123 supplements (yes/no) was collected from a self-reported questionnaire.

124

125 Physical activity was assessed using a self-reported questionnaire based on exercise outside of
126 school hours per week, with exercise defined in three categories for activity causing breathlessness
127 or sweating (≥ 4 times per week, 1-3 times per week and < once per week). Annual family income
128 before tax was completed by the primary caregiver and reported in three categories (\leq \$40,000,
129 \$40,001-78,000 and > \$78,000). Family functioning was included in order to account for a number
130 of related family factors, including communication and parental conflict, allowing for a
131 parsimonious model whilst also considering the importance of family in offspring mental health.
132 Family functioning was measured using the 12-item general functioning scale (GFS) from the

133 McMaster Family Assessment Devise⁽³³⁾. The scale has been shown to be reliable and internally
134 consistent ⁽³⁴⁾, with lower scores on the GFS representing poorer family functioning and higher
135 scores representing better family functioning.

136

137 *Statistical analysis*

138

139 Characteristics of participants who completed the FFQ and the YSR at both 14 and 17 years were
140 compared with non-participants from the original cohort. Sex, race, family income during
141 pregnancy, maternal age at birth, maternal education and maternal pre-pregnancy BMI were
142 compared using Chi-square tests. Baseline characteristics were described for participants in the
143 current study, including sex, YSR T-scores (total, internalising and externalising), zinc and
144 magnesium intakes, energy intake, dietary misreporting, supplement use, BMI, physical activity,
145 family income and family functioning.

146

147 Zinc and magnesium intakes at 14 and 17 years were converted to z-scores within each follow-up
148 separately. General linear mixed models were used to investigate the prospective univariate
149 relationships between zinc and magnesium intakes and YSR T-scores (total, internalising and
150 externalising). Models were then adjusted for sex, physical activity, family income, supplement
151 status, dietary misreporting, BMI, family functioning and energy intake. Interactions between time
152 and zinc or magnesium intakes were explored in order to determine whether the effect of intakes on
153 the YSR-T scores were different at the two follow-ups. Similarly, interactions between sex and zinc
154 or magnesium intakes were investigated in order to determine whether there were sex differences in
155 the effect of zinc and magnesium intakes on YSR T-scores. Analyses were performed using IBM
156 SPSS Statistics Release Version 19.9.9.1 (IBM SPSS Inc., 2010, Chicago, IL). Statistical
157 significance was defined as $p < 0.05$.

158

159 **Results**

160

161 A total of 684 adolescents completed the YSR and FFQ at both follow-ups (Figure 1). Compared
162 with those from the original cohort who did not participate in the current study ($n = 2184$),
163 participants were more likely to be female, Caucasian, to come from families with a higher income
164 during pregnancy and to have mothers with a higher age, higher education during pregnancy and
165 healthier pre-pregnancy body mass index ($p < 0.05$).

166

167 Mean YSR total, internalising and externalising T-scores were approximately 50 at both follow-ups
168 (Table 1), which is consistent with population norms. Dietary zinc and magnesium intakes were
169 similar at 14 and 17 years: mean zinc intake was approximately 12 mg/day and magnesium intake
170 was approximately 310 mg/day. The mean intakes in this population were in line with the Estimated
171 Average Requirements for zinc and magnesium (zinc, 11 mg/day for males and 6 mg/day for
172 females; magnesium, 340 mg/day for males and 300 mg/day for females).

173

174 In univariate analyses ($n = 684$), zinc and magnesium intakes (per SD) were not significantly
175 associated with internalising or externalising behaviours over the three-year study period (Table 2).
176 However, after adjusting for potential confounders ($n = 667$ at 14 years and $n = 607$ at 17 years),
177 including sex, physical activity, family income, supplement use, dietary misreporting, BMI, family
178 functioning and energy intake, there was a significant inverse association between magnesium and
179 externalising behaviour problems. Although there was a trend towards improved externalising
180 behaviour problems with increased zinc intake, the association did not reach the statistically
181 significant level we had specified. There were no significant interactions between time and zinc or
182 magnesium intakes, and between sex and zinc or magnesium intakes. Further, there were no
183 significant associations between zinc and magnesium intakes and internalising behavior problems
184 or total YSR T-scores.

185

186 **Discussion**

187

188 This study examined the prospective associations between zinc and magnesium intakes and
189 internalising and externalising behaviour problems in adolescents. The results support our
190 hypothesis that dietary magnesium intakes are inversely associated with externalising behaviour
191 problems in adolescents. Although we found no significant associations between zinc and
192 internalising or externalising behaviours, there was a trend towards higher zinc intake and reduced
193 externalising behaviour problems. Externalising behaviour problems include attention problems,
194 rule-breaking behaviours and aggressive behaviours, meaning that there is some overlap between
195 our findings and previous research that found beneficial effects of magnesium supplementation on
196 symptoms of ADHD⁽²²⁻²⁴⁾. However, we did not find a significant association between zinc or
197 magnesium intake and internalising behaviour problems, which contrasts with previous literature<sup>(12-
198 15, 17, 18, 20)</sup>.

199

200 There are several reasons why magnesium intake may relate to externalising behaviour problems in
201 adolescents. Some insight is provided by considering symptoms of ADHD, which share

202 characteristics of externalising behaviours and may also be influenced by intake magnesium.
203 Magnesium plays a role in the function of the serotonergic, noradrenergic and dopaminergic
204 receptors, which are related to the pathophysiology of ADHD⁽³⁵⁾. Improved ADHD symptoms have
205 been reported in children after magnesium supplementation^(24, 36).

206
207 We found no prospective association between dietary zinc and internalising behaviour problems
208 (withdrawn, somatic complaints, anxious/depressed) in our study, which is consistent with results
209 from a longitudinal study of 2317 middle-aged Finnish men⁽³⁷⁾. In contrast, dietary intakes of zinc
210 have repeatedly shown an inverse relationship with depressive symptoms in cross-sectional
211 analyses, particularly in women^(12-15, 38-40). We also found no association between dietary
212 magnesium intakes and internalising behaviour problems, which is consistent with a study in 12,939
213 Spanish university graduates⁽²¹⁾. However, a number of cross-sectional studies have found an
214 inverse association between dietary magnesium intakes and depressive symptoms^(12, 20, 38, 41, 42).
215 Differences between our results and those reported elsewhere may stem, at least in part, from
216 differences in the age of participants, and the nature and duration of follow-up. Our study included
217 population-based adolescents followed from 14 to 17 years, whereas most of the previous literature
218 has included adult participants, often assessed cross-sectionally (in the case of population-based
219 studies) or in the context of a clinical trial. Further research is warranted to determine if zinc and
220 magnesium intakes relate to internalising problems in some age or demographic groups and not
221 others.

222
223 The equivocal results in studies examining dietary zinc and magnesium intakes and mental health
224 may also relate to the use of different mental health assessment tools. An advantage of our study is
225 the use of the YSR, since it distinguishes between internalising and externalising behaviour
226 problems - a differentiation that is not captured by all mental health measures. At the same time, the
227 YSR does not generate clinical diagnoses and we cannot comment on associations between dietary
228 intakes and clinically significant depression, anxiety or ADHD. Differences in how mental health
229 problems are conceptualised and assessed may contribute to differences in results across studies,
230 again speaking to the need for further research in this area.

231
232 Strengths of our study were the prospective study design, use of a validated food frequency
233 questionnaire, and extensive characterisation of a population-based cohort. The latter allowed us to
234 assess the effect of dietary zinc and magnesium intakes on mental health while accounting for a
235 wide range of potential confounding factors. A limitation of our study was the use of self-reported
236 questionnaire, rather than clinical diagnosis, to assess mental health problems. While self-report

237 assessment of mental health may lead to more truthful reporting than face-to-face assessment, self-
238 report measurements are subject to reporting bias. It can also be difficult to accurately assess
239 nutrient intakes using an FFQ. However, the FFQ used in this study was validated against a 3-day
240 food record in the same cohort and the mean daily intakes of zinc and magnesium were similar
241 when measured by the FFQ and the 3-day food record⁽²⁹⁾.

242

243 It is possible that behaviour problems result in altered appetite and eating habits, including
244 increased consumption of processed foods, which are lower in minerals such as zinc and
245 magnesium. Furthermore, growing evidence suggests that obesity may be related to numerous
246 psychiatric disorders, and several behavioural and biological pathways have been proposed to
247 explain this potential relationship, which are outside the realm of nutrition⁽⁴³⁾. In adjusting for
248 confounders, we have attempted to present evidence for a causative relationship; however, we
249 cannot rule out the possibility of reverse causality or residual confounding. A further limitation of
250 the study was the loss to follow-up. Participants included in the current study were more likely to be
251 from families with higher socioeconomic status relative to participants from the original cohort and
252 care should be taken when generalising results to the wider community. However, although attrition
253 may have been higher for those participants suffering mental health difficulties, the YSR T-scores
254 in the current study reflect the population norm.

255

256 Given that dietary magnesium intake can be optimised through the consumption of nutrient-dense
257 foods and supplementation, our study has important public health implications. Promoting increased
258 consumption of magnesium-rich foods, such as green leafy vegetables, legumes, nuts, seeds and
259 whole grains, along with supplementation to address identified micronutrient deficiencies, may be a
260 useful strategy to prevent mental health and behavioural problems in adolescents. In order to
261 determine any benefit of magnesium and/or zinc supplementation in the prevention and treatment of
262 externalising behaviour problems, further randomised controlled trials using optimal doses are
263 necessary.

264 Table 1. Characteristics of the Raine Study participants for whom Youth Self Report and
 265 micronutrient intakes were available at both the 14 and 17 year follow-ups ($n = 684$)

	14 year follow-up		17 year follow-up	
	<i>n</i>		<i>n</i>	
Sex (%)				
Male	319	46.6	319	46.6
Female	365	53.4	365	53.4
Youth Self Report T-scores (mean, SD)				
Total	684	49.6 (9.0)	684	51.0 (9.7)
Internalising	684	47.3 (9.4)	684	48.9 (10.6)
Externalising	684	49.2 (9.5)	684	50.7 (10.1)
Zinc [mg/day (mean,SD)]	684	12.4 (4.2)	684	12.6 (5.5)
Magnesium [mg/day (mean, SD)]	684	308.3 (103.8)	684	311.8 (135.6)
Energy intake [kcal/day (mean, SD)]	684	2253.5 (726.7)	684	2305.5 (1012.1)
Dietary reporting (%)				
Under-reporter	286	41.8	372	54.5
Plausible-reporter	352	51.5	272	39.9
Over-reporter	46	6.7	38	5.6
Supplement status (%)				
Supplement user	94	13.7	177	25.9
Supplement non-user	590	86.3	507	74.1
Body mass index [kg/m ² (median, IQR)]	683	20.1 (4.3)	682	21.9 (4.2)
Physical activity (%)				
≥ 4 times per week	219	32.1	169	25.8
1-3 times per week	397	58.1	349	53.4
< once per week	67	9.8	136	20.8
Family income (%)				
≤ \$40,000 per year	160	23.7	93	14.5
\$40,001-78,000 per year	272	40.4	194	30.2
> \$78,000 per year	242	35.9	355	55.3
266 Family functioning (mean, SD)	676	1.8 (0.4)	648	1.8 (0.5)

267 SD, standard deviation; IQR, interquartile range

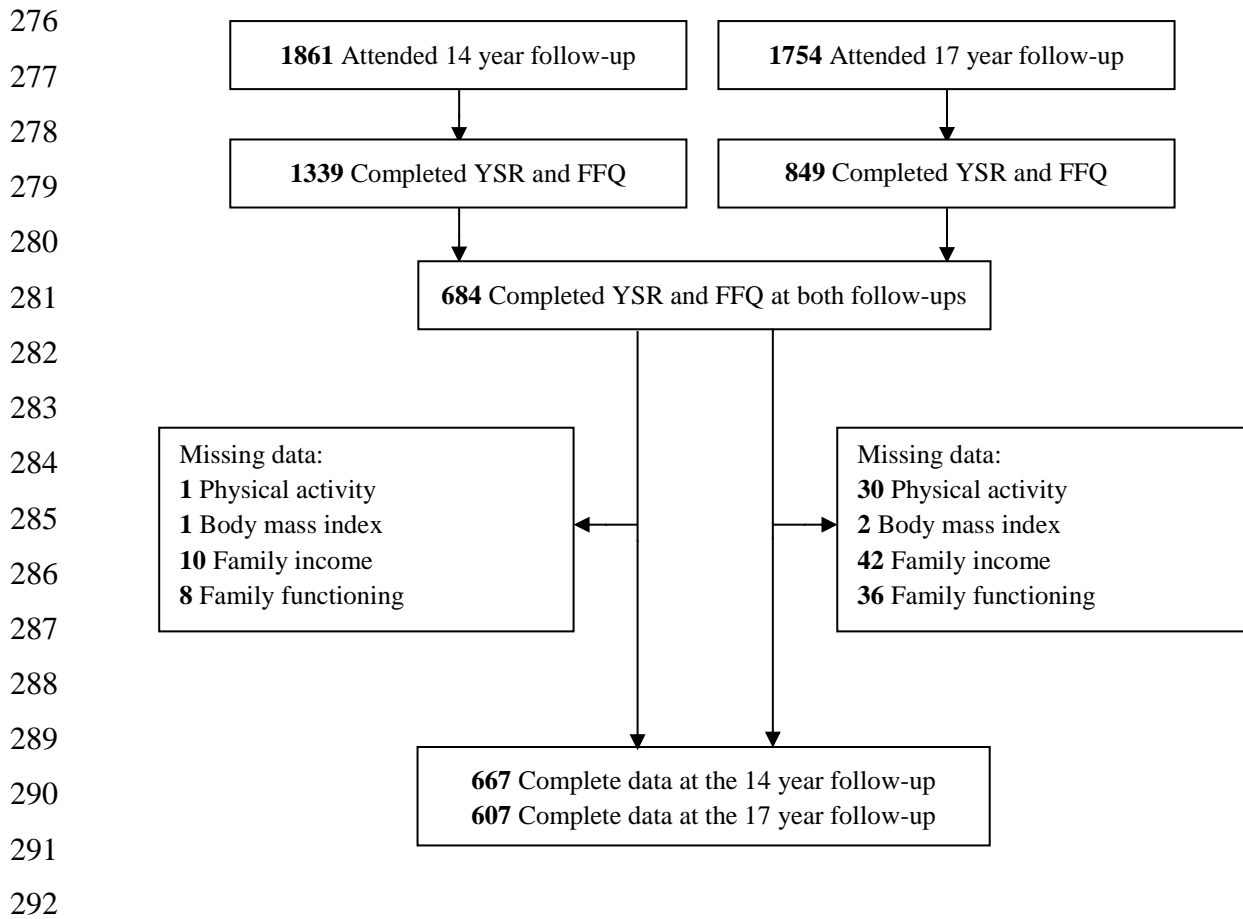
268 Table 2. General linear mixed model coefficients for Youth Self Report T-scores and zinc and
 269 magnesium intakes at ages 14 and 17 years

	Zinc		Magnesium	
	β (95% CI) ¹	<i>p</i>	β (95% CI) ¹	<i>p</i>
	Unadjusted			
Total	0.35 (-0.25, 0.96)	0.256	0.31 (-0.16, 0.80)	0.191
Internalising	0.09 (-0.58, 0.76)	0.796	0.01 (-0.51, 0.54)	0.961
Externalising	0.35 (-0.28, 0.98)	0.273	0.39 (-0.11, 0.89)	0.126
	Adjusted ²			
Total	-0.48 (-1.29, 0.32)	0.241	-0.44 (-1.35, 0.47)	0.342
Internalising	-0.07 (-0.97, 0.84)	0.887	0.52 (-0.50, 1.53)	0.316
270 Externalising	-0.73 (-1.57, 0.10)	0.085	-1.45 (-2.40, -0.50)	0.003

271 ¹Estimated difference in Youth Self Report T-scores per standard deviation increase in zinc and
 272 magnesium intakes

273 ²Adjusted for sex, physical activity, family income, supplement status, dietary misreporting, BMI,
 274 family functioning and energy intake; n = 667 at 14 years, n = 607 at 17 years

275



293 Figure 1. Flow diagram of adolescents attending the 14 and 17 year follow-ups

294 YSR, Youth Self-Report; FFQ, food frequency questionnaire

295 **References**

- 296 1. Frederickson CJ, Koh JY, Bush AI (2005) The neurobiology of zinc in health and disease. *Nat*
297 *Rev Neurosci* **6**, 449-462.
- 298 2. Takeda A (2012) Zinc signaling in the hippocampus and its relation to pathogenesis of
299 depression. *J Trace Elem Med Biol* **26**, 80-84.
- 300 3. Smart TG, Xie X, Krishek BJ (1994) Modulation of inhibitory and excitatory amino acid receptor
301 ion channels by zinc. *Prog Neurobiol* **42**, 393-441.
- 302 4. Franco JL, Posser T, Brocardo PS *et al.* (2008) Involvement of glutathione, ERK1/2
303 phosphorylation and BDNF expression in the antidepressant-like effect of zinc in rats. *Behav Brain*
304 *Res* **188**, 316-323.
- 305 5. Krocicka B, Branski P, Palucha A *et al.* (2001) Antidepressant-like properties of zinc in rodent
306 forced swim test. *Brain Res Bull* **55**, 297-300.
- 307 6. Szewczyk B, Poleszak E, Sowa-Kucma M *et al.* (2010) The involvement of NMDA and AMPA
308 receptors in the mechanism of antidepressant-like action of zinc in the forced swim test. *Amino*
309 *Acids* **39**, 205-217.
- 310 7. Morris ME (1992) Brain and CSF magnesium concentrations during magnesium deficit in
311 animals and humans: neurological symptoms. *Magnes Res* **5**, 303-313.
- 312 8. Eby GA, Eby KL (2006) Rapid recovery from major depression using magnesium treatment.
313 *Med Hypotheses* **67**, 362-370.
- 314 9. Singewald N, Sinner C, Hetzenauer A *et al.* (2004) Magnesium-deficient diet alters depression-
315 and anxiety-related behavior in mice--influence of desipramine and Hypericum perforatum extract.
316 *Neuropharmacology* **47**, 1189-1197.
- 317 10. Whittle N, Li L, Chen WQ *et al.* (2011) Changes in brain protein expression are linked to
318 magnesium restriction-induced depression-like behavior. *Amino Acids* **40**, 1231-1248.
- 319 11. Henrotte JG, Franck G, Santarromana M *et al.* (1997) Mice selected for low and high blood
320 magnesium levels: a new model for stress studies. *Physiol Behav* **61**, 653-658.
- 321 12. Jacka FN, Maes M, Pasco JA *et al.* (2012) Nutrient intakes and the common mental disorders in
322 women. *J Affect Disord* **141**, 79-85.
- 323 13. Amani R, Saeidi S, Nazari Z *et al.* (2010) Correlation between dietary zinc intakes and its serum
324 levels with depression scales in young female students. *Biol Trace Elem Res* **137**, 150-158.
- 325 14. Roy A, Evers SE, Avison WR *et al.* (2010) Higher zinc intake buffers the impact of stress on
326 depressive symptoms in pregnancy. *Nutr Res* **30**, 695-704.

- 327 15. Maserejian NN, Hall SA, McKinlay JB (2012) Low dietary or supplemental zinc is associated
328 with depression symptoms among women, but not men, in a population-based epidemiological
329 survey. *J Affect Disord* **136**, 781-788.
- 330 16. Sawada T, Yokoi K (2010) Effect of zinc supplementation on mood states in young women: a
331 pilot study. *Eur J Clin Nutr* **64**, 331-333.
- 332 17. Nowak G, Siwek M, Dudek D *et al.* (2003) Effect of zinc supplementation on antidepressant
333 therapy in unipolar depression: a preliminary placebo-controlled study. *Pol J Pharmacol* **55**, 1143-
334 1147.
- 335 18. Siwek M, Dudek D, Paul IA *et al.* (2009) Zinc supplementation augments efficacy of
336 imipramine in treatment resistant patients: a double blind, placebo-controlled study. *J Affect Disord*
337 **118**, 187-95.
- 338 19. Ranjbar E, Kasaei MS, Mohammad-Shirazi M *et al.* (2013) Effects of zinc supplementation in
339 patients with major depression: a randomized clinical trial. *Iran J Psychiatry* **8**, 73-79.
- 340 20. Jacka FN, Overland S, Stewart *et al.* (2009) Association between magnesium intake and
341 depression and anxiety in community-dwelling adults: the Hordaland Health Study. *Aust N Z J*
342 *Psychiatry* **43**, 45-52.
- 343 21. Derom ML, Martinez-Gonzalez MA, Sayon-Orea Mdel C *et al.* (2012) Magnesium intake is not
344 related to depression risk in Spanish university graduates. *J Nutr* **142**, 1053-1059.
- 345 22. Akhondzadeh S, Mohammadi MR, Khademi M (2004) Zinc sulfate as an adjunct to
346 methylphenidate for the treatment of attention deficit hyperactivity disorder in children: a double
347 blind and randomized trial. *BMC Psychiatry* **4**, 9.
- 348 23. Bilici M, Yildirim F, Kandil S *et al.* (2004) Double-blind, placebo-controlled study of zinc
349 sulfate in the treatment of attention deficit hyperactivity disorder. *Prog Neuropsychopharmacol Biol*
350 *Psychiatry* **28**, 181-190.
- 351 24. Mousain-Bosc M, Roche M, Polge A *et al.* (2006) Improvement of neurobehavioral disorders in
352 children supplemented with magnesium-vitamin B6. I. Attention deficit hyperactivity disorders.
353 *Magnes Res* **19**, 46-52.
- 354 25. Newnham JP, Evans SF, Michael CA *et al.* (1993) Effects of frequent ultrasound during
355 pregnancy: a randomised controlled trial. *Lancet* **342**, 887-891.
- 356 26. Achenbach TM (1991) Manual for the Youth Self-Report and 1991 profile. Burlington:
357 University of Vermont.
- 358 27. Achenbach TM, Rescorla L (2001) The Manual for the ASEBA School-Age Forms and
359 Profiles. Burlington: University of Vermont.
- 360 28. Baghurst KI, Record SJ (1984) A computerised dietary analysis system for use with diet diaries
361 or food frequency questionnaires. *Community Health Stud* **8**, 11-18.

- 362 29. Ambrosini GL, de Klerk NH, O'Sullivan TA et al. (2009) The reliability of a food frequency
363 questionnaire for use among adolescents. *Eur J Clin Nutr* **63**, 1251-1259.
- 364 30. Lewis J, Hunt A (1995) NUTTAB95 Nutrient Data Table for Use in Australia. Canberra:
365 Australian Government Publishing Service.
- 366 31. Holland B, Unwin I, Buss DH et al. (1993) McCance and Widdowson's The Composition of
367 Foods. 5th ed. London: Royal Society of Chemistry.
- 368 32. Poslusna K, Ruprich J, de Vries JHM et al. (2009) Misreporting of energy and micronutrient
369 intake estimated by food records and 24 hour recalls, control and adjustment methods in practice.
370 *Br J Nutr* **101**, S73-S85.
- 371 33. Epstein NB, Baldwin LM, Bishop DS (1983) The McMaster Family Assessment Device. *J*
372 *Marital Fam Ther* **9**, 171-80.
- 373 34. Byles J, Byrne C, Boyle MH et al. (2004) Ontario Child Health Study: reliability and validity of
374 the general functioning subscale of the McMaster Family Assessment Device. *Fam Process* **27**, 97-
375 104.
- 376 35. Cardoso CC, Lobato KR, Binfare RW et al. (2009) Evidence for the involvement of the
377 monoaminergic system in the antidepressant-like effect of magnesium. *Prog*
378 *Neuropsychopharmacol Biol Psychiatry* **33**, 235-242.
- 379 36. Starobrat-Hermelin B, Koziolec T (1997) The effects of magnesium physiological
380 supplementation on hyperactivity in children with attention deficit hyperactivity disorder (ADHD).
381 Positive response to magnesium oral loading test. *Magnes Res* **10**, 149-156.
- 382 37. Lehto SM, Ruusunen A, Tolmunen T et al. (2013) Dietary zinc intake and the risk of depression
383 in middle-aged men: a 20-year prospective follow-up study. *J Affect Disord* **150**, 682-685.
- 384 38. Davison KM, Kaplan BJ (2012) Nutrient intakes are correlated with overall psychiatric
385 functioning in adults with mood disorders. *Can J Psychiatry* **57**, 85-92.
- 386 39. DiGirolamo AM, Ramirez-Zea M, Wang M et al. (2010) Randomized trial of the effect of zinc
387 supplementation on the mental health of school-age children in Guatemala. *Am J Clin Nutr* **92**,
388 1241-1250.
- 389 40. Yary T, Aazami S (2012) Dietary intake of zinc was inversely associated with depression. *Biol*
390 *Trace Elem Res* **145**, 286-290.
- 391 41. Jung KI, Ock SM, Chung JH et al. (2010) Associations of serum Ca and Mg levels with mental
392 health in adult women without psychiatric disorders. *Biol Trace Elem Res* **133**, 153-161.
- 393 42. Yary T, Aazami S, Soleimannejad K (2013) Dietary intake of magnesium may modulate
394 depression. *Biol Trace Elem Res* **151**, 324-329.
- 395 43. Marsha D, Wildes JE (2012) Obesity in DSM-5. *Psychiat Ann* **11**, 431-435.