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# Dietary quality linkage to overall competence at school and emotional disturbance in representative Taiwanese young adolescents: dependence on gender, parental characteristics and personal behaviors

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## Abstract

**Background:** Child school performance during puberty may be at increased risk through emotional disturbance. It is hypothesized that this may be mitigated by dietary quality.

**Methods:** In a nationally representative sample (Nutrition and Health Survey in Taiwan, NAHSIT), 1371 Taiwanese aged 11–16 years, overall competence at school, (OCS) and emotional status have been assessed by teachers with the SAED (Scale for Assessing Emotional Disturbance). Parents provided family socio-demographics and students completed a behavioral and dietary questionnaire (Youth Healthy Eating Index - Taiwan, YHEI-TW). Associations between emotional disturbance (ED), OCS and dietary quality (YHEI-TW) were assessed in multiple linear regression models with adjustments for covariates including parental characteristics, personal behaviors, body fatness and puberty.

**Results:** Boys or girls with ED had a less favorable OCS ($p < 0.001$), minimally dependent on YHEI-TW. On multivariable analysis there was a more positive association between OCS and YHEI-TW among boys ($\beta = 0.05$, $p < 0.01$) and girls ($\beta = 0.07$, $p < 0.001$). Poor dietary quality was associated with ED, especially in girls ($\beta = -0.06$, $p < 0.001$). Additionally, parental characteristics, body fatness, and personal behaviors are associated with OCS. Puberty is associated with ED and may be indirectly linked to OCS.

**Conclusions:** Unsatisfactory food intake is associated with the link between emotional disturbance and impaired school performance, as assessed by OCS, especially among girls. For both genders, socio-economic and behavioral factors including parenteral income, reading, screen viewing and smoking are modulators of this association. Puberty was a modifying factor in girls. Dietary quality is a relevant factor for health (ED) as well as education (OCS) during early adolescence.

**Keywords:** Gender, Parental characteristics, Personal behaviors, Dietary quality, Puberty, Junior high school, School performance

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# Background

Adolescence, nowadays considered the transitional period between childhood and adulthood, is a critical time in human development when pubertal change is underway, personal identity is being formatted and when future livelihood prospects are being established [1], especially through the education system. Minimizing emotional disturbance (ED) [2, 3] and optimizing school performance [4] at this time is a desirable research and policy objective. However, associations between ED and school performance are poorly documented [5, 6]. There is a growing recognition that items in the SAED (scale for assessing emotional disturbance) methodology [7] may be linked to overall competence at school (OCS) as a surrogate for school performance [8, 9] or learning disability [10]. A number of factors could affect any association between ED and OCS. These include home environment, school environment [11, 12], personal behaviors such as recreation and physical activity, cigarette smoking & alcohol usage [11], dietary quality [8, 13] nutritional status insofar as body fatness is concerned [14], and pubertal development [11].

*Diet* may also be a key factor in the expression of emotional disturbance [13, 14] and in cognitive and school performance [8, 15–18]. It may operate through energy regulation in conjunction with physical activity and sedentariness given that cognitive function appears amenable to measures which alter cellular energy regulation [19, 20], particularly in relation to the increasing burden of the metabolic syndrome and diabetes [21, 22]. Dietary quality has also been shown to play a role in emotion, mood [23] and mental performance [13] where limited food biodiversity, notably of plant foods, and degree of processing, with more ready-to-eat low nutrient density food items are the riskier consumption patterns [18, 23, 24]. However, there are limited observations about the connectedness of dietary patterns and brain function in relation to the child-adult transition. Partly, this is because of the biological heterogeneity and its secular trends at this time of reproductive transition.

*Parents* have the potential to affect both ED and OCS in many ways which reflect their continuing, if declining, role as providers of care, support and resources during their offspring's adolescence [25]. This is likely to include pathways like diet [24, 26]. This is the case during elementary school where, particularly in girls vulnerable through low birth weight, nutritious diets have been associated with less likelihood of both emotional disturbance and poor school performance [13]. Further documentation and understanding of these phenomena may prompt guardians and mentors of young people to identify and act preventatively in regard to them, especially in regard to food choice and diet [2, 27].

*Our principal hypothesis* is that emotional disturbance (ED) during the child-to-adult transition is adversely associated with school performance as represented by overall competence (OC) and that dietary quality may mitigate such a linkage This association may, nevertheless, be modulated by various factors. The opportunity has been taken to study emotional disturbance and school performance among junior high school boys and girls in Taiwan in regard to diet and puberty, taking into account parental and various personal behavioral characteristics.

# Methods

## Study participants

Participants were adolescents aged 11–16 years (grade 7–9) who participated in the Nutrition and Health Survey in Taiwan (NAHSIT) 2010–2011. The original study is a national representative cross-sectional survey. All of Taiwan's 358 townships/districts were classified into 5 strata (northern 1, northern 2, central, southern and eastern area) by geographical location and population density. The survey used the PPS (probabilities proportional to sizes) sampling method to select 1620 students from 30 junior high schools (6 schools from each stratum) randomly. NAHSIT comprises questionnaires administered by face-to-face interview of parents and students (including a food frequency questionnaire, 24-h dietary recall, pubertal development, personal behaviors from students; and family socio-demographics from parents). Physical examination (including body composition, blood pressure) was conducted and plasma metabolic analytes obtained though venipuncture by a health care professional. Thus, the questionnaire covered both dietary and non-dietary health factors [28].

The present study excluded participants who did not complete the emotional disturbance questionnaire, leaving 1371 (656 boys and 715 girls) junior high school students eligible for analysis. The survey was approved by the Institutional Review Board of the National Health Research Institutes, Taiwan.

## Measures

### The scale for assessing emotional disturbance (SAED)

The modified Scale for Assessing Emotional Disturbance (SAED) was used to assess the NAHSIT students' school and social performance, the original questionnaires being developed by Epstein and Cullinan [13, 29, 30]. The SAED scales for students were assessed by their teachers using the SAED questionnaire. The SAED is a rating scale designed to help identify students with emotional and/or behavioral difficulties at school. Its test-retest reliability coefficient is above > 0.80, and most of its subscales have inter-rater reliability coefficients over 0.79 [7]. The Chinese modification of SAED as used in this study has a high overall reliability of 0.92 and validity of

Huang *et al. Nutrition Journal* (2018) 17:29

Page 3 of 14

0.76 [29]. The SAED consist of a total of seven subscales including OC considered in this study as OCS and six other subscales. These are: Inability to Learn (IL, 8 items), Relationship Problems (RP, 6 items), Inappropriate Behavior (IB, 10 items), Unhappiness or Depression (UD, 7 items), Physical Symptoms or Fears (PF, 8 items)), Social Maladjustment (SM, 6 items), and Overall Competence at school (OCS, 7 items). OCS has been treated separately from SAED in this study (see below). Within the above subscales, items were scored by each student's Class Mentor teacher. As previously described, the first six subscales (52 items) were scored on a four-point scale (0 = not a problem, 1 = mild problem, 2 = considerable problem, 3 = severe problem), and five-point scale for OCS (0 = far below average, 1 = below average, 2 = average, 3 = above average, and 4 = far above average). The raw scores for the SAED subscales were summed and converted into standardized scores (mean = 10 and SD = 3). Compared with the Taiwanese Non-Emotional Disturbance Norms, a substantially deviant SAED score (except OCS) is indicated by a score that above the 91 percentile (>90th percentile), which corresponds to Z-scores ≥13 [29]. Therefore, a score of 13 was chosen as the cut point. Children with a Z-score ≥ 13 were considered to have emotional disturbance (ED). IL, RP, IB, UD, and PF scores could be combined to produce a total score of ED characteristics. These five subscale scores plus SM score can be combined to yield an "SAED total" score [30, 31].

### Overall competence at school (OCS)

OCS was used to assess the students' overall performance and adaptation at school. The questions for OCS included (1) intellectual functioning, (2) family support for school, (3) overall level of academic functioning, (4) motivation for schoolwork, (5) level of peer support, (6) personal hygiene (e.g. grooming, dressing), and (7) interest in activities outside of school. Students with an OCS Z-score less than or equal to 6 (fell below the 9th percentile) were considered to have an unfavorable overall school performance [29, 30].

### Dietary quality (YHEI-TW)

The Youth Healthy Eating Index-Taiwan (YHEI-TW) is a diet quality scoring system modified from the U.S. YHEI, which captures the adolescent's diet quality by assessing his or her adherence to dietary guidelines [32]. The YHEI–TW scores were obtained from daily consumption of 11 components derived from food frequency questionnaires and a 24–hour dietary recall employed during NAHSIT: (1) whole grains (0 to ≥ 2 servings, 0–10 points), (2) vegetables (0 to ≥ 3 servings, 0–10 points), (3) fruits (0 to ≥ 3 servings, 0–10 points), (4) dairy (0 to ≥ 3 servings, 0–10 points), (5) meat ratio (0 to ≥ 20, 10–0 points), (6) snack foods (i.e., salty snacks and snacks with added sugar, 0 to ≥ 3 servings, 10–0 points), (7) sweetened beverages (0 to ≥3 servings, 10–0 points), (8) multivitamins (never-daily, 5–0 points), (9) fried foods outside of home (never-daily, 0–5 points), (10) consumption of breakfast (never to > 5 times/week, 0–5 points) and (11) dinner with family (prepared by family member, 5 points). It does not take into account butter/margarine and visible animal fat, which were part of the original YHEI (US), since consumption of these items has been negligible in Taiwan. In all cases, except component 11 (dinner patterns), scores were derived in a proportionate manner. Thus, total scores range from 0 to 90, where higher scores indicate better dietary quality [13, 33, 34].

### Covariate measurements

Covariates were derived from questionnaires, by anthropometry and from laboratory measurements of metabolic analytes in the NAHSIT survey. Those considered in the present study included mother's education (lower than university, university and above), household income (0–30,000, 30,000–50,000, 50,000–80,000, > 80,000 NTD/month where US$1 = NTD 30), ever smoking (no, yes), read during weekdays (0–1, 1–3, ≥3 h/day), watch TV during weekdays (0–1, 1–3, ≥3 h/day), play computer games during weekdays (0–1, 1–3, ≥3 h/day), moderate or heavy physical activity (0–30, ≥30 min/day; in accordance with Taiwanese recommendations) [35], BMI (underweight, normal, overweight, obesity; (the Childhood Obesity Expert Panel of the Taiwanese Department of Health defines 'obesity' and 'overweight' (≥95th and ≥85th percentile value of body mass index (BMI), respectively) using age- and gender-specificity percentiles for BMI (each gender and year of age from 2 to 18 had its own cut-off point for overweight and for obesity) [36], and puberty (boys: beard growth (not yet, at first, in progress, completed); girls: menarche (yes, no)).

### Statistical analysis

Chi-square tests were used to assess the significant differences between categorical variables. We used t tests to assess differences in continuous variables. Categorical variables are presented as percentages (%), and continuous variables are presented as means (standard errors, SE). Multiple linear regression models (MLRs) were used to test associations between the key determinants (household, personal behaviors, puberty, dietary quality, body fatness) and outcome measures (ED and OCS); and in the adjustments for mother's education, household income, ever smoking, reading during weekdays, watching TV during weekdays, playing computer games during weekdays, moderate or heavy physical activity, pubertal development and BMI. Full models were considered

Huang *et al. Nutrition Journal* (2018) 17:29

Page 4 of 14

which included all relevant variables. The regression co-efficients reported are from these models. Statistical significance was set at $p < 0.05$. Data were analyzed using SAS 9.3 for Windows, weighted by SUDAAN [37]. SUDAAN was also used to adjust for the study design effect of cluster sampling to obtain unbiased estimates of the standard errors.

An overview of the study design and models is provided in Fig. 1.

## Results

### Overall competence at school

Table 1 shows the junior high school students' characteristics by overall competence as an index of school performance. The mean age of the 1371 participants (51.7% are boys) was 13.6 years. There were 5.9% adolescents with unfavorable overall competence at school (OCS) (OCS Z-score ≤ 6). The percentage in boys was higher than girls (61.3% vs. 38.7%, $p = 0.042$). Adolescents had a better OCS when parents had a higher education. Adolescents in households where income was less than 30,000 NTD/month (about 1000 US dollars) had the most unfavorable OCS (34.5%), whereas this was only 11.2% in the > 80,000 NTD/month group ($p < 0.001$).

### Personal Behaviors

Compared with favorable OCS, more smokers were found among unfavorable OCS (24.5%, $p = 0.019$), those who read only 0–1 h/day during weekdays (67.2%, $p = 0.01$), those who watched TV ≥3 h/day during weekdays

(12.9%, $p = 0.006$), and those who played computer games ≥3 h/day during weekdays (13.6%, $p = 0.064$).

### Dietary Quality

Participants with unfavorable OCS had lower dietary scores than did those with favorable OCS (44.0 ± 1.1 vs. 48.4 ± 0.5, $p < 0.001$) and also a higher consumption frequency (times/week) of fast foods (0.7 ± 0.1 vs. 0.4 ± 0.1, $p = 0.029$), sugary beverages (6.5 ± 0.6 vs. 5.3 ± 0.2, $p = 0.053$), and flavored milk (1.4 ± 0.3 vs. 0.7 ± 0.1, $p = 0.015$), but a lower cheese consumption (0.6 ± 0.1 vs. 0.9 ± 0.1, $p = 0.035$) (Table 2).

### Puberty

In regard to pubertal development, boys with 'completed' beard growth had the most unfavorable OCS (4.5%, $p = 0.036$) (Table 2). The means of YHEI-TW scores were not significant difference among onset of puberty in the present study (data not shown).

### Body fatness and Metabolic analytes

Adolescents with an unfavorable OCS had a higher BMI and a lower HDL cholesterol than did those with a better OCS (BMI: 21.9 ± 0.5 vs. 20.8 ± 0.2, $p = 0.046$; HDL: 50.8 ± 1.9 vs. 55.6 ± 0.7, $p = 0.022$) (Table 2).

### Emotional disturbance

Figure 2 shows the SAED Z-scores of adolescents by dietary quality (< or ≥ YHEI-TW median). The median YHEI-TW for boys was 48.2, and 48.5 for girls.



**Fig. 1** Pathways to emotional disturbance and overall competence at school in Taiwanese adolescents.
Where an association is significant, the level of significance is indicated with the relevant *p* value and in accordance with gender. The findings represented in this figure are those of the present report except for "obesity→emotional disturbance" which have been reported in Reference [14] for Taiwanese schoolchildren

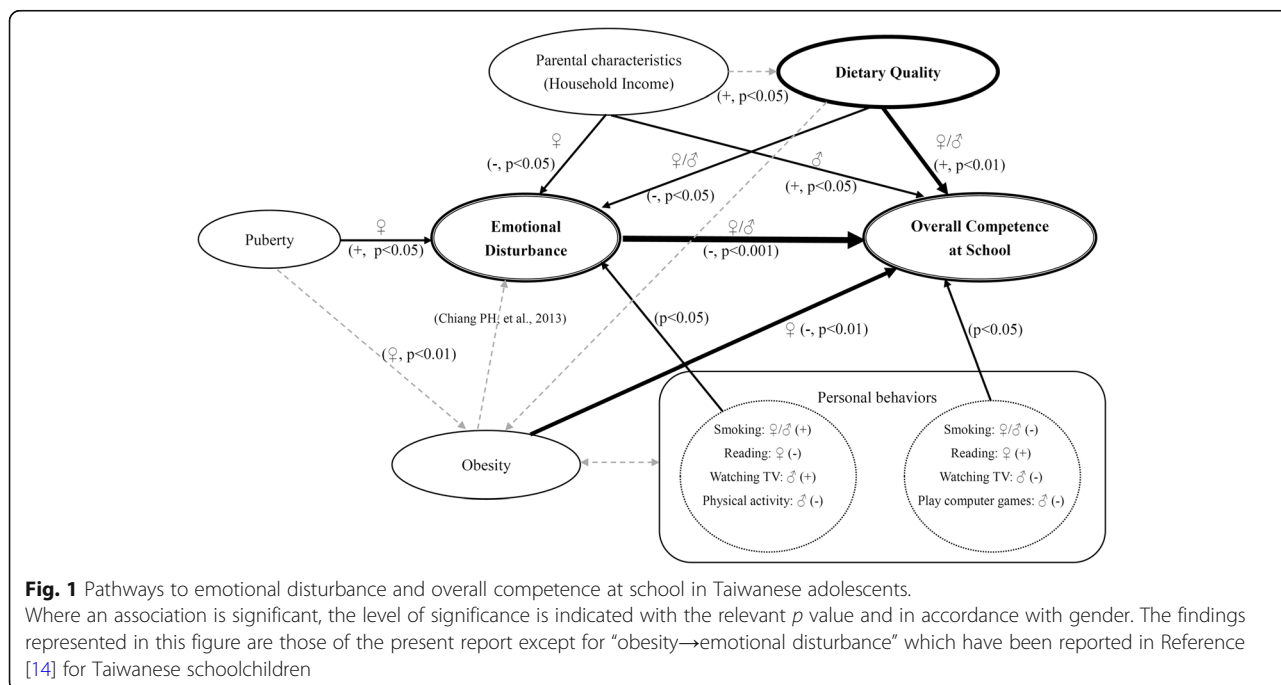Huang *et al. Nutrition Journal* (2018) 17:29

Page 5 of 14

**Table 1** Basic characteristics of junior high school students by Overall Competence (OCS) (*N* = 1371)

| Characteristics[a] | | OCS[b] | | P value |
|---|---|---|---|---|
| | Overall | Z-score ≤ 6 | Z-score > 6 | |
| Participants (%) | 1371 (100) | 98 (5.9) | 1273 (94.1) | |
| Mean age in years (SE) | 13.6 (0.1) | 13.3 (0.1) | 13.6 (0.1) | 0.130 |
| Gender (%) | | | | 0.042 |
| Boys | 51.7 | 61.3 | 51.1 | |
| Girls | 48.3 | 38.7 | 48.9 | |
| Father's ethnicity (%) | | | | 0.777 |
| Fukienese | 76.6 | 71.9 | 76.9 | |
| Hakka | 13.0 | 15.8 | 12.8 | |
| Mainlander | 8.3 | 9.2 | 8.2 | |
| Indigenes | 2.2 | 3.2 | 2.1 | |
| Father's educational level (%) | | | | 0.008 |
| Secondary education and below | 40.5 | 61.9 | 39.1 | |
| University and above | 59.5 | 38.1 | 60.9 | |
| Mother's educational level (%) | | | | 0.018 |
| Secondary education and below | 33.4 | 47.5 | 32.5 | |
| University and above | 66.6 | 52.5 | 67.5 | |
| Household income (%) | | | | <0.001 |
| 0–30,000 NTD/month[c] | 19.3 | 34.5 | 18.4 | |
| 30,000–50,000 NTD/month | 21.7 | 24.1 | 21.6 | |
| 50,000–80,000 NTD/month | 29.8 | 30.1 | 29.6 | |
| > 80,000 NTD/month | 29.2 | 11.2 | 30.3 | |
| Ever smoking (%) | | | | 0.019 |
| No | 89.9 | 75.5 | 90.8 | |
| Yes | 10.1 | 24.5 | 9.19 | |
| Drinking alcohol (%) | | | | 0.730 |
| No | 87.4 | 85.4 | 87.6 | |
| Yes | 12.6 | 14.6 | 12.4 | |
| Read during weekdays (%) | | | | 0.010 |
| 0–1 (h/day) | 45.6 | 67.2 | 44.3 | |
| 1–3 | 42.0 | 30.0 | 42.8 | |
| ≥ 3 | 12.4 | 2.9 | 13.0 | |
| Watch TV during weekdays (%) | | | | 0.006 |
| 0–1 (h/day) | 58.1 | 33.9 | 59.7 | |
| 1–3 | 33.7 | 53.2 | 32.5 | |
| ≥ 3 | 8.13 | 12.9 | 7.8 | |
| Play computer games during weekdays (%) | | | | 0.064 |
| 0–1 (h/day) | 62.3 | 48.8 | 63.2 | |
| 1–3 | 29.2 | 37.6 | 28.7 | |
| ≥ 3 | 8.45 | 13.6 | 8.1 | |
| Moderate or heavy physical activity (%) | | | | 0.734 |
| 0–30 (min/day) | 26.0 | 24.7 | 26.1 | |
| ≥ 30 | 74.0 | 75.3 | 73.9 | |

[a]Categorical variables are presented as percentage (%), and continuous variables are presented as mean (SE)
[b]Students with an OCS Z-score less than or equal to 6 were considered to have unfavorable overall school performance
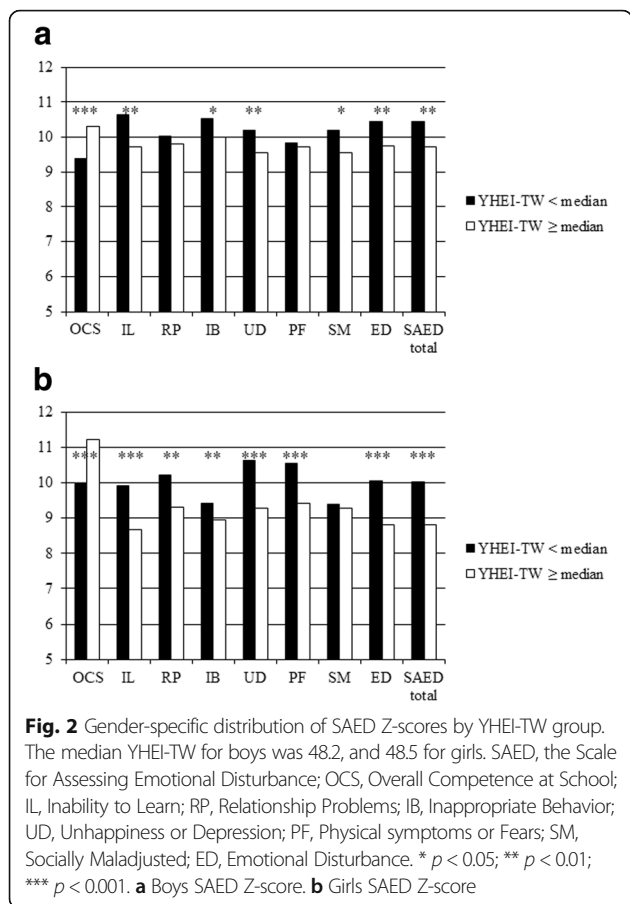[c]1 US dollars = 30 NTD

**Table 2** Student food intakes, physical examination and metabolic analytes by Overall Competence (OCS)

| | Overall | OCS[a] | | *p* value |
|---|---|---|---|---|
| | | Z-score ≤ 6 | Z-score > 6 | |
| Mean (SE) Dietary score (YHEI-TW) | 48.1 (0.5) | 44.0 (1.1) | 48.4 (0.5) | <0.001 |
| Mean (SE) Food consumption (times/week) | | | | |
|   Fast foods consumption | 1.7 (0.1) | 2.3 (0.3) | 1.7 (0.1) | 0.086 |
|   Fast foods from fast food chain store | 0.5 (0.1) | 0.7 (0.1) | 0.4 (0.1) | 0.029 |
|   Fast foods from non-fast food chain store | 1.3 (0.1) | 1.6 (0.3) | 1.2 (0.1) | 0.206 |
|   Sugary beverages consumption | 5.4 (0.2) | 6.5 (0.6) | 5.3 (0.2) | 0.053 |
| Dairy products consumption | | | | |
|   Milk | 3.5 (0.2) | 3.0 (0.7) | 3.6 (0.2) | 0.499 |
|   Flavored milk | 0.7 (0.1) | 1.4 (0.3) | 0.7 (0.1) | 0.015 |
|   Yoghurt | 0.5 (0.1) | 0.7 (0.2) | 0.5 (0.1) | 0.342 |
|   Cheese | 0.9 (0.1) | 0.6 (0.1) | 0.9 (0.1) | 0.035 |
| Development of puberty | | | | |
| Menarche (girls only) (%) | | | | 0.929 |
|   Yes | 94.0 | 93.5 | 94.0 | |
|   No | 6.0 | 6.5 | 6.0 | |
| Beard growth (boys only) (%) | | | | 0.036 |
|   Not yet | 33.4 | 45.3 | 32.4 | |
|   At first | 31.4 | 36.9 | 30.9 | |
|   In progress | 33.8 | 13.2 | 35.4 | |
|   Completed | 1.5 | 4.5 | 1.2 | |
| Mean (SE) Body compositions | | | | |
|   Height (cm) | 161 (0.3) | 160 (1.2) | 161 (0.3) | 0.716 |
|   Weight (kg) | 54.2 (0.5) | 56.7 (1.7) | 54.0 (0.5) | 0.146 |
|   Body mass index (BMI, kg/m$^2$) | 20.8 (0.2) | 21.9 (0.5) | 20.8 (0.2) | 0.046 |
|   Triceps skin fold thickness (TSF, mm) | 16.6 (0.4) | 17.2 (0.9) | 16.6 (0.4) | 0.496 |
|   Mid Arm Muscle Circumference (MAMC, cm) | 20.0 (0.2) | 21.5 (1.2) | 19.9 (0.2) | 0.221 |
|   waist circumference (WC, cm) | 74.2 (0.5) | 76.2 (1.2) | 74.1 (0.5) | 0.114 |
| Mean (SE) Blood pressure (mmHg) | | | | |
|   Systolic blood pressure (SBP) | 105 (0.5) | 106 (1.5) | 105 (0.5) | 0.520 |
|   Diastolic blood pressure (DBP) | 60.5 (0.7) | 61.5 (1.2) | 60.4 (0.7) | 0.301 |
| Mean (SE) Plasma metabolic analytes | | | | |
|   Fasting glucose (mg/dL) | 95.4 (0.4) | 95.2 (0.9) | 95.4 (0.4) | 0.835 |
|   Total cholesterol (mg/dL) | 158 (1.4) | 155 (3.3) | 159 (1.4) | 0.191 |
|   Triglycerides (mg/dL) | 71.4 (1.8) | 78.3 (5.5) | 71.0 (1.7) | 0.150 |
|   HDL cholesterol (mg/dL) | 55.3 (0.7) | 50.8 (1.9) | 55.6 (0.7) | 0.022 |
|   LDL cholesterol (mg/dL) | 88.8 (1.2) | 87.9 (3.2) | 88.8 (1.2) | 0.761 |
|   Uric acid (mg/dL) | 5.8 (0.1) | 6.2 (0.2) | 5.74 (0.1) | 0.063 |

[a]Students with an OCS Z-score less than or equal to 6 were considered to have unfavorable overall school performance
YHEI-TW, Youth Healthy Eating Index-Taiwan

Whether boys or girls, those with better diet quality had higher overall competence at school ($p < 0.001$). Boys with poorer diet quality had higher IL, IB, UD, SM, ED and total SAED Z-scores compared to those with better diet quality ($p < 0.05$). Among girls, those with poorer diet quality demonstrated more emotional disturbance (except SM) compared to those with better diet quality ($p < 0.01$).

Huang *et al. Nutrition Journal* (2018) 17:29

Page 7 of 14



**Fig. 2** Gender-specific distribution of SAED Z-scores by YHEI-TW group. The median YHEI-TW for boys was 48.2, and 48.5 for girls. SAED, the Scale for Assessing Emotional Disturbance; OCS, Overall Competence at School; IL, Inability to Learn; RP, Relationship Problems; IB, Inappropriate Behavior; UD, Unhappiness or Depression; PF, Physical symptoms or Fears; SM, Socially Maladjusted; ED, Emotional Disturbance. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. **a** Boys SAED Z-score. **b** Girls SAED Z-score



**Fig. 3** Z-scores of Overall Competence at school (OCS) by SAED sub-items and gender. Students with Z-scores ≥13 in any subscale were classified as having emotional disturbance. The t-test was used to compared the difference between two SAED sub-items groups; all of the results were significant ($p < 0.001$). **a** Boys OCS Z-score. **b** Girls OCS Z-score

**Emotional disturbance and overall competence at school**

Figure 3 shows the significant difference between total SAED and its sub-types with OCS as Z-scores < or ≥13. Whether boys or girls, students with emotional disturbance (Z-score ≥ 13) had significantly lower OCS Z-scores. Students without emotional disturbance had a better overall competence at school than those with emotional disturbance ($p < 0.001$). There were significant inverse associations between OCS and SAED and its sub-items among boys and girls (Additional file 1). When these relationships for SAED itself and its sub-items were adjusted for dietary quality, the β coefficients in the range of − 0.32 to − 0.85 were marginally reduced by the order of 0.01–0.05 in boys and girls, but remained significant; this indicated that a contribution from dietary quality to ED-linked OCS was small (Additional file 1).

**Predictive models for OCS**

The multiple linear regression analysis for OCS Z-scores, with reference to YHEI-TW and relevant co-variates, is shown in Fig. 4. In conjunction with other co-variates, there was a significant positive association between OCS and YHEI-TW among boys (β = 0.05, $p < 0.01$) and girls (β = 0.07, $p < 0.001$). Boys with a household income of 50–
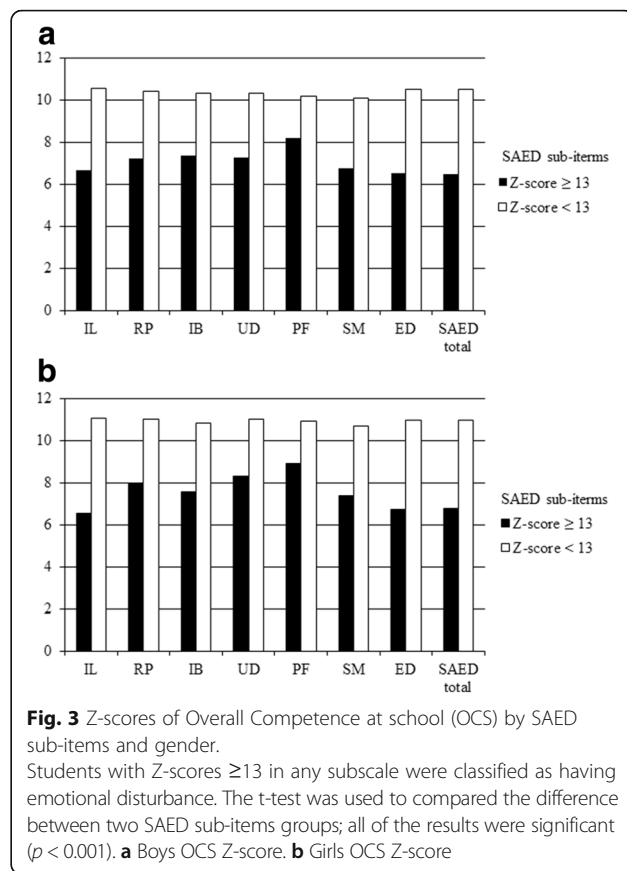
80,000 NTD/month had an OCS Z-score which was 1.02 greater than for those with < 30,000 NTD/ month ($p <$ 0.05). Compared with not smoking, not watching TV, and not playing computer games 0–1 h/day during weekdays, boys who did had lower OCS Z-scores (β = − 1.26 ($p <$ 0.05), − 0.76 ($p < 0.05$), and − 0.93 ($p < 0.001$) respectively. For girls, ever smoking and obesity were associated with lower OCS Z-scores than their non-smoking and normal weight counterparts (β was − 0.97 ($p < 0.05$) and − 1.34 ($p$ < 0.01) respectively). Girls who read ≥3 h/day during weekdays had higher OCS Z-scores than did those who read 0–1 h/day (β = 1.23, $p < 0.05$).

The $R^2$ for the complete model to predict OCS was 0.21 for boys and 0.22 for girls, explaining 21% and 22% of the variance respectively; without YHEI-TW in the model, $R^2$ was 0.18 and 0.16 (18% and 16% of the variance respectively) (Fig. 4).

**Predictive models for SAED**

Tables 3 and 4 show the multiple linear regressions for SAED subscales with reference to YHEI-TW and relevant co-variates. There was a significant inverse association between IL and YHEI-TW (β = − 0.05, $p < 0.01$) among boys. In the multivariable models, boys who had ever smoked had higher IL (β = 1.87, $p < 0.05$), IB (β = 1.88, $p < 0.01$),

Huang *et al. Nutrition Journal* (2018) 17:29

Page 8 of 14



**Fig. 4** Socio-demographic, behavioral, nutritional and pubertal β-coefficients from MLRs[a] for the Overall Competence Z-score by gender.
[a] MLRs, Multiple Linear Regressions. The $R^2$ for the complete model to predict OCS was 0.21 for boys and 0.22 for girls. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. **a** Boys. **b** Girls
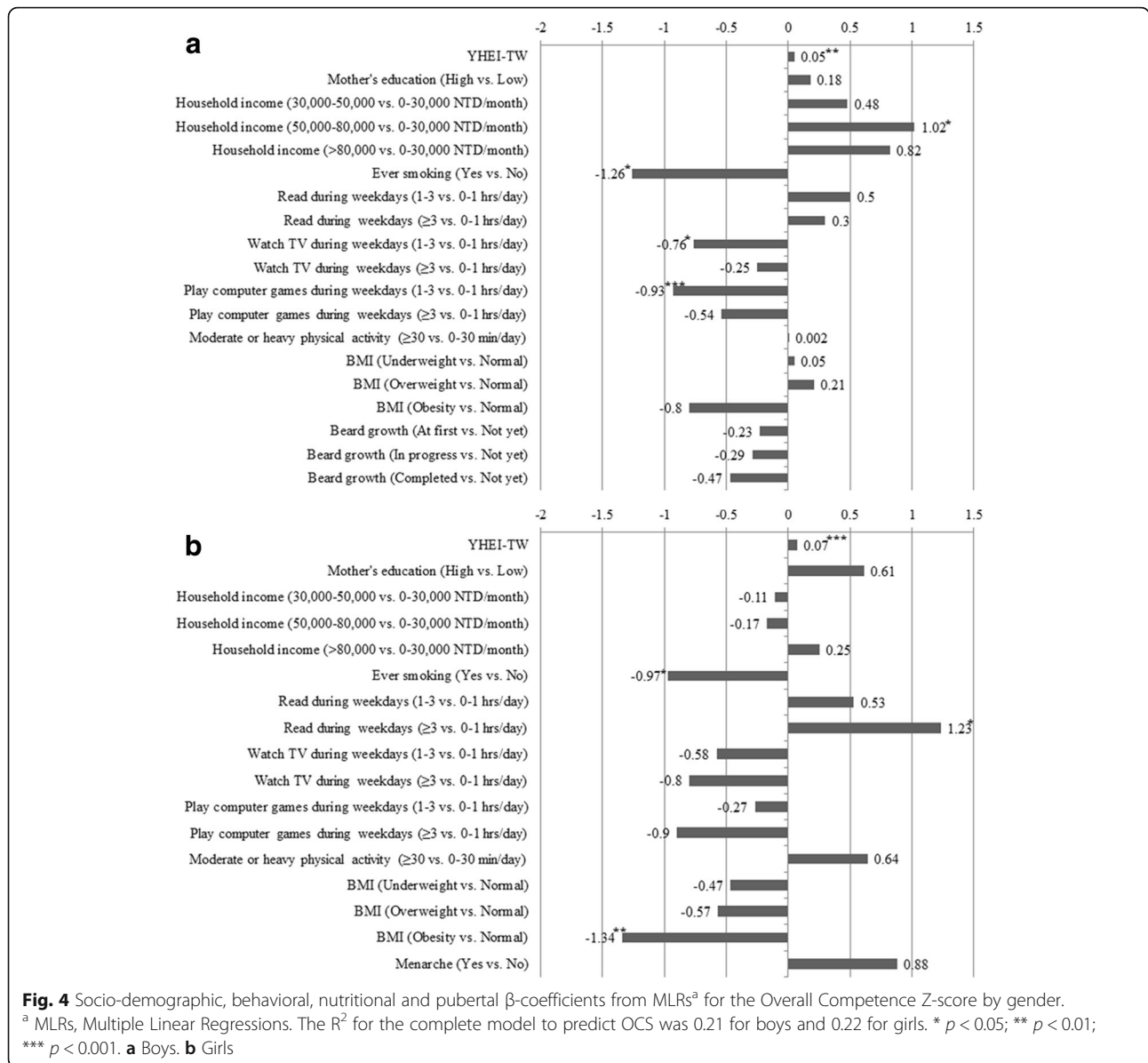
SM (β = 2.15, $p < 0.05$), ED (β = 1.65, $p < 0.05$), and SAED total (β = 1.73, $p < 0.05$) Z-scores. Compared with 0–1 h/ day, boys who watched TV ≥ 3 h/day during weekdays were positively associated with PF (β = 2.03, $p < 0.01$) and ED (β = 1.53, $p < 0.05$) Z-scores, but negatively associated with the SM (β = − 0.99, $p < 0.05$) Z-score. Boys who engaged in moderate or heavy physical activity (≥ 30 min/ day) had lower PF Z-scores than did those who reported 0–30 min/day (β = − 0.75, $p < 0.05$). Among girls, there were significant inverse associations between SAED subscale (except IB and SM) and YHEI-TW Z-scores. Girls' households with 50,000–80,000 NTD/month income had lower IB, ED, and SAED total Z-scores (β values were − 0.69 ($p < 0.05$), − 0.97 ($p < 0.01$), and − 0.95 ($p < 0.01$), respectively) compared with those from the lowest

household income group (0–30,000 NTD/month). Girls who had ever smoked had greater IL (β = 1.62, $p < 0.01$), IB (β = 1.96, $p < 0.01$), ED (β = 1.78, $p < 0.05$), and SAED total (β = 1.78, $p < 0.05$) Z-scores than those who never smoked. Unlike boys, there were significant negative associations between reading and IL, IB, SM, ED, and SAED total Z-scores among girls. In addition, girls who had entered menarche had higher PF (β = 1.2, $p < 0.01$) and SM (β = 0.34, $p < 0.05$) Z-scores than those who had not.

The $R^2$ for the complete model to predict SAED was 0.13 for boys and 0.21 for girls, explaining 13.4% and 20.6% of the variance respectively; without YHEI-TW in the model, $R^2$ was 0.13 and 0.15 (12.9% and 15.0% of the variance).

Dietary quality (YHEI-TW) is associated with overall competence at school (OCS) as shown in Figs. 1 and 4 (β =

**Table 3** Socio-demographic, behavioral, nutritional and pubertal β-coefficients from MLRs[a] with R-square for SAED sub-items[b] in boys

| Characteristics | SAED Z-score | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IL | RP | IB | UD | PF | SM | ED | SAED total |
| YHEI-TW | −0.05** | − 0.02 | − 0.01 | − 0.01 | 0.0002 | − 0.02 | − 0.03 | − 0.03 |
| Mother's education (Ref: Low) | | | | | | | | |
| High (University and above) | − 0.36 | 0.45 | 0.25 | 0.01 | −0.08 | 0.25 | −0.002 | 0.01 |
| Household income (Ref: 0–30,000 NTD/month)[c] | | | | | | | | |
| 30,000–50,000 NTD/month | − 0.56 | − 0.40 | − 0.26 | 0.56 | 0.35 | 0.51 | − 0.21 | − 0.16 |
| 50,000–80,000 NTD/month | − 0.92 | − 0.78 | − 1.13 | − 0.30 | − 0.06 | − 0.28 | − 0.91 | − 0.89 |
| > 80,000 NTD/month | − 0.67 | − 0.37 | − 0.55 | − 0.15 | 0.36 | − 0.53 | − 0.47 | − 0.48 |
| Ever smoking (Ref: No) | | | | | | | | |
| Yes | 1.87* | 0.22 | 1.88** | 1.23 | 0.38 | 2.15* | 1.65* | 1.73* |
| Read during weekdays (Ref: 0–1 h/day) | | | | | | | | |
| 1–3 h/day | − 0.26 | −0.24 | − 0.59 | − 0.50 | − 0.12 | − 0.03 | −0.44 | −0.42 |
| ≥ 3 h/day | − 0.22 | −0.45 | − 0.49 | −0.30 | 0.05 | 0.11 | −0.36 | −0.34 |
| Watch TV during weekdays (Ref: 0–1 h/day) | | | | | | | | |
| 1–3 h/day | 0.31 | 0.21 | −0.40 | 0.45 | 0.05 | −0.38 | 0.14 | 0.11 |
| ≥ 3 h/day | 1.19 | 0.50 | 1.02 | 1.61 | 2.03** | −0.99* | 1.53* | 1.40 |
| Play computer games during weekdays (Ref: 0–1 h/day) | | | | | | | | |
| 1–3 h/day | 0.46 | 0.26 | 0.72 | 0.66 | 0.49 | 0.55 | 0.65 | 0.66 |
| ≥ 3 h/day | 0.002 | 0.41 | 0.78 | 0.08 | −0.71 | −0.35 | 0.20 | 0.17 |
| Moderate or heavy physical activity (Ref: 0–30 min/day) | | | | | | | | |
| ≥ 30 min/day | 0.07 | 0.35 | −0.40 | 0.08 | −0.75* | −0.37 | − 0.14 | −0.16 |
| BMI (Ref: Normal weight) | | | | | | | | |
| Underweight | 0.08 | 0.10 | −0.19 | −0.22 | − 0.35 | 0.35 | − 0.11 | −0.08 |
| Overweight | −0.15 | 1.32 | 0.66 | 0.46 | 0.02 | 0.74 | 0.46 | 0.49 |
| Obesity | 0.88 | 0.50 | −0.22 | −0.06 | −0.15 | − 0.38 | 0.34 | 0.30 |
| Beard growth (Boys only) (Ref: Not yet) | | | | | | | | |
| At first | −0.39 | 0.004 | −0.09 | 0.07 | 0.04 | −0.03 | −0.16 | − 0.16 |
| In progress | −0.62 | − 0.74 | −0.63 | −0.31 | −0.43 | − 0.34 | −0.70 | − 0.70 |
| Completed | −0.02 | − 0.50 | 0.55 | − 0.70 | −0.13 | − 0.16 | −0.09 | − 0.10 |
| $R^2$ with YHEI-TW | 0.175 | 0.049 | 0.124 | 0.097 | 0.083 | 0.123 | 0.133 | 0.134 |
| $R^2$ without YHEI-TW | 0.159 | 0.047 | 0.124 | 0.096 | 0.083 | 0.119 | 0.128 | 0.129 |

[a]MLRs, Multiple Linear Regressions
[b]The Scale for Assessing Emotional Disturbance (SAED) sub-items including Inability to learn (IL), Relationship problems (RP), Inappropriate behavior (IB), Unhappiness or depression (UD), Physical symptoms or fears (PF), Socially maladjusted (SM), and Emotional Disturbance (ED)
[c]1 US dollars = 30 NTD
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

0.05, $p < 0.01$ for boys; 0.07 with $p < 0.001$ for girls). It is also associated with ED in boys and girls. In particular, there is a significant inverse association between IL and YHEI-TW (β = − 0.05, $p < 0.01$) among boys (Table 3). Among girls, there are significant inverse associations between the SAED subscales (except IB and SM) and YHEI-TW Z-scores (β for IL = − 0.05 ($p < 0.001$), for RP β = − 0.05 ($p < 0.001$), for UD β = − 0.07 ($p < 0.001$), for PF β = − 0.06 (p < 0.01), for ED β = − 0.06 ($p < 0.001$), and for SAED β = − 0.06 ($p < 0.001$)) (Fig. 1 and Table 4).

Thus, dietary quality appears to be linked to OCS directly and also indirectly via ED. The possibility that it might have been linked indirectly through an association with obesity was not evident in the present study (regression Model for BMI on YHEI-TW, β = 0.004 for boys and − 0.002 for girls, $p > 0.05$ (data not shown)).

In turn, dietary quality may have many determinants of the food system and choice. In this study, we only report household income as a surrogate for socio-economic status. It was positively correlated

Huang *et al. Nutrition Journal* (2018) 17:29

Page 10 of 14

**Table 4** Socio-demographic, behavioral, nutritional and pubertal β-coefficients from MLRs[a] with R-square for SAED sub-items[b] in girls

| Characteristics | SAED Z-score | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IL | RP | IB | UD | PF | SM | ED | SAED total |
| YHEI-TW | −0.05*** | −0.05*** | −0.03 | −0.07*** | −0.06** | −0.004 | −0.06*** | −0.06*** |
| Mother's education (Ref: Low) | | | | | | | | |
|   High (University and above) | −0.19 | 0.14 | 0.45 | 0.15 | 0.88 | 0.17 | 0.26 | 0.26 |
| Household income (Ref: 0–30,000 NTD/month)[c] | | | | | | | | |
|   30,000–50,000 NTD/month | 0.12 | −0.51 | −0.41 | −0.66 | −0.91 | 0.06 | −0.44 | −0.42 |
|   50,000–80,000 NTD/month | −0.59 | −0.92 | −0.69* | −0.91 | −1.09 | −0.33 | −0.97** | −0.95** |
|   > 80,000 NTD/month | 0.01 | 0.02 | −0.27 | −0.35 | −0.59 | −0.17 | −0.24 | −0.24 |
| Ever smoking (Ref: No) | | | | | | | | |
|   Yes | 1.62** | 0.45 | 1.96** | 1.38 | 1.13 | 1.16 | 1.78* | 1.78* |
| Read during weekdays (Ref: 0–1 h/day) | | | | | | | | |
|   1–3 h/day | −0.32 | 0.36 | −0.39 | 0.34 | −0.12 | −0.07 | −0.13 | −0.13 |
|   ≥ 3 h/day | −1.35** | −0.44 | −0.73* | −0.17 | −0.20 | −0.38* | −0.91* | −0.90* |
| Watch TV during weekdays (Ref: 0–1 h/day) | | | | | | | | |
|   1–3 h/day | 0.19 | −0.38 | 0.25 | −0.17 | −0.40 | 0.16 | −0.02 | −0.01 |
|   ≥ 3 h/day | 0.33 | −0.08 | −0.20 | 0.01 | −0.56 | 0.04 | −0.03 | −0.03 |
| Play computer games during weekdays (Ref: 0–1 h/day) | | | | | | | | |
|   1–3 h/day | 0.21 | 0.10 | 0.02 | 0.12 | 0.13 | −0.16 | 0.15 | 0.14 |
|   ≥ 3 h/day | 0.96 | 1.19 | 1.66 | 0.92 | 0.81 | 0.10 | 1.40 | 1.35 |
| Moderate or heavy physical activity (Ref: 0–30 min/day) | | | | | | | | |
|   ≥ 30 min/day | −0.49 | −0.54 | −0.84 | 0.18 | −0.49 | −0.46 | −0.59 | −0.60 |
| BMI (Ref: Normal weight) | | | | | | | | |
|   Underweight | 0.61 | −0.31 | 0.24 | 0.61 | 0.32 | 0.33 | 0.43 | 0.44 |
|   Overweight | 0.78 | 0.44 | 0.15 | 0.68 | −0.14 | 0.27 | 0.54 | 0.54 |
|   Obesity | 0.38 | 1.21 | 0.43 | 0.62 | 0.34 | 0.01 | 0.67 | 0.65 |
| Menarche (Girls only) (Ref: No) | | | | | | | | |
|   Yes | −0.23 | 0.50 | 0.63 | 0.85 | 1.20** | 0.34* | 0.55 | 0.55 |
| $R^2$ with YHEI-TW | 0.207 | 0.122 | 0.173 | 0.152 | 0.143 | 0.079 | 0.207 | 0.206 |
| $R^2$ without YHEI-TW | 0.167 | 0.094 | 0.160 | 0.092 | 0.091 | 0.078 | 0.150 | 0.150 |

[a]MLRs, Multiple Linear Regressions
[b]The Scale for Assessing Emotional Disturbance (SAED) sub-items including Inability to learn (IL), Relationship problems (RP), Inappropriate behavior (IB), Unhappiness or depression (UD), Physical symptoms or fears (PF), Socially maladjusted (SM), and Emotional Disturbance (ED)
[c]1 US dollars = 30 NTD
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

with YHEI-TW for boys and girls respectively (Fig. 1). Compared with those from lowest income group (0–30,000 NTD/month), students' household income over 80,000 NTD/month had higher YHEI-TW scores (β = 5.45 ($p < 0.001$) for boys, and 3.19 ($p < 0.05$) for girls) (data not shown).

## Discussion

Unsatisfactory food intake is associated with the link between emotional disturbance and impaired school performance, as assessed by OCS, especially among girls. For both genders, socio-economic and behavioral factors including parenteral income, reading, screen viewing, and smoking are modulators of this association. Puberty was a modifying factor in girls. Dietary quality is a relevant factor for health (ED) as well as educational (OCS) during early adolescence.

### Emotional disturbance and overall competence at school (OCS)

For the various measures of emotional disturbance reflected in SAED, there were consistently negative associations with OCS. These findings confirm several published studies [38–41]. Even so, a number of factors may be contributory to this relationship. The focus of the present investigation is how dietary quality might affect

any such linkage. Linear regression for this association for boys and girls explains 44% and 42% of the variance, respectively (data not shown). There is a small contribution of dietary quality to OCS via ED evident in the β coefficients of the MLRs which are uniformly less when these models are adjusted for YHEI-TW However, dietary quality in boys and girls is directly associated with OCS in our analysis. This link remains independent of other covariates on MLRs. Thus OCS is dependent on ED, YHEI-TW and various independent covariates, namely, in boys, household income (favorably, screen viewing (unfavorably)) along with smoking (unfavorably) and, in girls, weekday reading (favorably) and body fatness (unfavorably along with smoking (unfavorably)).

### Dietary quality and pattern

The present study has found that better dietary quality is associated with better overall competence at school and lower emotional disturbance. This supports reports, like that among Australian adolescents, that 'Western' dietary patterns characterized by energy-dense take-away 'fast' foods, plentiful red and processed meat, soft drinks, and other deep-fried and refined foods scores are associated with poorer academic performance (especially in mathematics and reading) [42]. For 14-year olds, this dietary pattern is associated with diminished cognitive performance 3 years later, at age 17 [43]. On the other hand, fruit and vegetable intake has a positive association with school performance among adolescents, as found in the Palestinian Gaza Strip [44]. Insofar as dairy foods are concerned, there may be differences within the category since OCS was less with flavored milk and greater with cheese; since all dairy products were treated together in the YHEI-TW, this may have accounted for non-significant associations on multiple linear regression for dairy. There is evidence that vitamin K-2 as found in cheese may play a role in brain function [45–47]. Of particular interest, regular breakfast, in its own right, is associated with better school performance, suggesting a role for diurnal dietary pattern in brain function [8, 17].

Previous studies in Taiwan show a dose-response for food diversity scores and health outcomes in adults, but comparable data are not available for children [48]. There is a gradient across the range, so that the upper quartile probably constitutes a desirable goal for food diversity at all ages. UN system data for dietary diversity and household food security support this position [49, 50].

The present study adds to a growing literature on the utility of YHEI-TW in children of dominantly Chinese ancestry and culture in the evaluation of diet in child development. These include studies of birth weight, food patterns and school performance [13] and of intergenerational dietary interplay in communities [34].

### Parental characteristics

In this study, adolescents who had a better OC in school had parents with higher educational achievements. Children's school performance has previously been found to be strongly and positively associated with parental education [51].

Where household incomes were less, OCS was correspondingly less good. Similarly, in the US, youths with serious emotional disturbance have been observed to come from lower income families than for those youths without disturbance [52].

### Personal behaviors

Smoking, reading, watching TV, playing computer games, and limited physical activity in the present study were associated with less OCS and with emotional disturbance. Likewise, smoking among adolescents has been associated with poor school performance and less study time [53]. Although causality is difficult to ascertain, clustering of riskier behaviors among adolescents is found with mood disturbance and includes smoking, substance use and self-harm or suicidal attempts [54].

### Who are the students at risk-puberty and gender?

Although it is a difficult life stage to evaluate, because of its variable and changing time of onset, it is one of the most socio-biologically critical developmental periods. It is known that school environments in Taiwan, including their food systems and recreational settings, are associated with pubertal development, although differentially in girls and boys [11]. In the present study, the peri-pubertal period is evidently one of emotional and educational vulnerability, notably in girls, judged by both the indices of learning and mood examined. After the menarche, PF and SM were increased. However, dietary quality is a mitigating factor and food intake an addressable behavior.

### What are the factors of greatest concern for adolescents in development and schooling?

Of the potential independent risk factors for emotional disturbance or school performance (OCS or sub-scales), diet (YHEI-TW), socio-economic advantage (household income) and reading were favorable, while screen viewing, smoking, puberty and greater BMI were unfavorable. These findings closely correspond to a Korean study of health behaviors and academic performance in adolescents, especially for diet and smoking, except that it found physical activity to be significant [26]. In the present study, for girls, we found BMI to be independently associated with OCS, which may have captured physical activity information.

In an Australian study of children and adolescents 4–17 years of age, internet usage and electronic gaming was found to be a mental health risk [55]. There are likely to be different internet usage patterns in a dominantly

Huang *et al. Nutrition Journal* (2018) 17:29

Page 12 of 14

Chinese as opposed to multicultural, but mainly European, Australian society with different cultural restraints and expectations of young adolescents. The gender difference in Taiwan of internet associations would also suggest this in the present study. It is an area in which more detailed analysis is required.

### Strengths and weaknesses

The adolescent population studied was representative of that in Taiwan, albeit dominantly Han Chinese with ancient and recent origins in mainland China. Indigenes were also studied and no differences in findings were apparent; this may represent a sampling limitation as previously observed, even though over-sampling of minorities, with SUDAAN adjustment for representativeness, has been undertaken in the present study [56]. Further cross-cultural extrapolation may be unwarranted, especially to other food cultures and educational systems. Other studies suggest limited generalizability to North-East Asian settings in general, but not dominantly European settings as in Australia, as discussed above. The cross-sectionality of the study begs the question of the medium to long-term health and performance outcomes of diet, along with other significant associated factors. As always with observational studies, residual confounding may be a problem in interpretation.

### Implications for health and nutrition policy and practice

Population-wide and representative evidence is provided in this study for children of dominantly Chinese ancestry and culture that dietary quality, along with parental input and personal behaviors is associated with emotional status and school performance. Intervention studies in support of these findings would add confidence to policy and practice which sought to enhance school performance by diet. In the meantime, household, school and community encouragement for healthier dietary patterns should be a low risk-high benefit option.

### Conclusions

The most supportable link of dietary quality to OCS is apparently direct rather than through ED to which it is also related in the present study. While ED is associated with OCS, and the intake of foods of limited nutritional value is seen with ED, the linkage of ED to OCS is minimally dependent on dietary quality. For both genders, socio-economic, parental education, reading or screen viewing, and smoking were associated with ED and OCS These factors may modulate the association between ED and OCS. Thus, the ways by which diet may affect OCS as a basis of school performance are likely to be complex.

## Additional file

Additional file 1: β-coefficients from the linear regressions for the Overall Competence (OC) and SAED Z-score. (DOCX 14 kb)

### Abbreviation

ED: Emotional disturbance; IB: Inappropriate behavior; IL: Inability to learn; NAHSIT: Nutrition and health survey in Taiwan; OC: Overall competence; OCS: Overall competence at school; PF: Physical symptoms or fears; RP: Relationship problems; SAED: Scale for assessing emotional disturbance; SM: Social maladjustment; UD: Unhappiness or depression; YHEI-TW: Youth healthy eating index – Taiwan

### Availability of data and materials
Our study used the NAHSIT (Nutrition and Health Survey in Taiwan) dataset, which is third party data. The NAHSIT data set is only available on application to the Taiwanese office of National Nutrition Survey for researchers who meet the criteria for access to confidential data. Data requests may be sent to the Nutrition Survey office (kuangmao@ibms.sinica.edu.tw). The data set is available for applicant use only. The present authors were granted access to these data. The data used in this paper were collected for the "Nutrition and Health Survey in Taiwan on Junior High School Students (NAHSIT 2010-2011)" sponsored by the Food and Drug Administration, Department of Health, Executive Yuan (99TFDA-FS-408).

### Authors' contributions
PHC and MLW designed the study. LYH performed the analyses. MSL provided assistance with interpretation. MLW and LYH wrote the paper. All authors critically read and approved the manuscript. The data were available to all authors.

### Ethics approval and consent to participate
The survey was approved by the Institutional Review Board of the National Health Research Institutes, Taiwan (IRB number: EC1051201-E).

### Consent for publication
Not applicable.

### Competing interests
The authors declare that they have no competing interests.

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Huang *et al. Nutrition Journal* (2018) 17:29

Page 13 of 14

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Huang *et al. Nutrition Journal* (2018) 17:29

Page 14 of 14

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