Supplementary Material Table1.

Questions used to assess the 18 ADHD DSM-IV symptoms.

|  |  |
| --- | --- |
| *ITEMS* | *QUESTION ASKED* |
| Hyperactivity/ impulsivity\*: | 1. *Do you have difficulties holding your hands and feet still or can you not stay seated?* 2. *Do you get up and move about in situations when you are supposed to remain seated?* 3. *Are you restless?* 4. *Do you have difficulty doing calm leisure pursuit?* 5. *Does it often feel like you are “on the go”?* 6. *Do you often talk excessively?* 7. *Do you often blurt out answers before the question has been completed?* 8. *Do you have difficulty awaiting turns?* 9. *Do you often interrupt or intrude on others?* |
| Inattention\* | 1. *Do you often fail to pay close attention to details or make careless mistakes when you write, or other activities?* 2. *Do you often have difficulty sustaining attention in tasks or activities?* 3. *Do you often seem not to listen when spoken to directly?* 4. *Do you often fail to follow instructions and to finish tasks?* 5. *Do you often have difficulty organising tasks and activities?* 6. *Do you often avoid tasks that require sustained mental effort?* 7. *Do you often lose things?* 8. *Are you often easily distracted or disturbed?* 9. *Are you often forgetful in daily activities?* |

*\* Response options: “Yes”=2; “Yes, to some extent”=1, “No”=0.*

Supplementary Material Table 2.

Questions used to assess symptoms for binge-eating behavior, binge-eating disorder (BED), and bulimia nervosa (BN)

|  |  |
| --- | --- |
| ITEMS/CRITERIA | *QUESTIONS ASSESSING ITEMS* |
| Eating binges | *“Have you ever had eating binges when you ate what most people would regard as an unusually large amount of food in a short period of time?”* |
| Loss of control over food intake ≥ 2 on the Likert scale defined as yes | “*When you were having eating binges, did you feel your eating was out of control?, with responses on a five point Likert scale,* *1. not at all, 2. slightly, 3. somewhat, 4. very much, 5. extremely* |
| Duration | *“For how long did you have binge eating episodes?” with response options: less than an month; 1-2 months, 3-5 months; 6 months to one year; more than a year* |
| Frequency | *“When you were binging the most, how many binges would you have in a month?”* |
| Influence of body shape and weight on self-evaluation | *“Weight and body shape do not at all, influence how I feel about myself” to “weight and body shape is most important for how I feel about myself.” Responses were on a 7 point Likert scale.* |
| Compensatory behaviors to avoid weight gain | *“Which of these did you use during the same time that you were binge eating? Making yourself vomit? Laxatives? Diuretics? Diet pills? Exercise more than 2 hours per day? Fast or not eat? Other methods?”* |
| Feeling distressed over binge eating ≥ 2 on the Likert scale defined as yes | *“How distressed or unhappy were you when binge eating?” with five point Likert scale: “1. not at all, 2. a little, 3. somewhat, 4. much, 5. extremely”* |
| DSM-5 symptoms for BED: scored positive if 3 or more questions were answered with yes | *“When you had eating binges did you: 1. eat much more rapidly than normal?; 2. eat until feeling uncomfortably full?; 3. eat large amounts of food when not feeling physically hungry?; 4. eat alone because of being embarrassed by how much one is eating?; 5. feel disgusted with yourself, depressed, or very guilty after overeating?”* |

Supplementary Material Table 3.

Associations of ADHD symptoms with binge-eating behavior, DSM-5 binge-eating behavior, binge-eating disorder (BED) and bulimia nervosa BN (adjusted for sex, age and controlled for the random effect of twins) compared with twins with no ADHD symptoms.

|  |  |  |  |
| --- | --- | --- | --- |
|  | n / all twins endorsing binge eating variables  and ADHD symptoms (%) | ADHD symptoms | |
| OR | 95% CI |
| Binge-eating behavior | 526 / 18,029 (2.92) | 3.65\*\*\* | (2.72, 4.91) |
| DSM-5 Binge-eating behavior1 | 290/ 17,948 (1.62) | 3.01\*\*\* | (2.09, 4.35) |
| Binge-eating disorder | 35/ 17,947 (0.20) | 2.55\* | (1.11, 5.86) |
| Bulimia nervosa | 229/ 17778 (1.29) | 3.09\*\*\* | (2.09, 4.56) |

OR - odds ratios, calculated from mixed effect logistic regression adjusted for sex, age and controlled for the random effect of twins.

1 Binge eating behavior with DSM-5 requirements for duration (at least 3 months) and frequency (at least once a week)

95% CI – 95% confidence interval, \*P < 0.05; \*\*P < 0.01; \*\*\*P < 0.001.

Supplementary Material Table 4.

Phenotypic correlations, intra-class correlations, and cross-twin-cross-trait correlations for ADHD symptoms and binge-eating behavior in 13,773 female twins (3664 complete twin pairs: 2156 MZ and 1508 DZ pairs), adjusted for age (linear), and males set as missing

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type of correlation | | Estimate | (95% CI) | Z | P-value |
| Phenotypic correlation | MZ female | 0.21 | (0.15, 0.26) | 0.31 | 0.76 |
|  | DZ female | 0.20 | (0.16, 0.24) |  |  |
| Intra-class correlation ADHD | MZ female | 0.43 | (0.39, 0.47) | 6.72 | <.0001 |
|  | DZ female | 0.23 | (0.17, 0.28) |  |  |
| Intra-class correlation binge-eating behavior | MZ female | 0.65 | (0.54, 0.75) | 13.86 | <.0001 |
|  | DZ female | 0.30 | (0.09, 0.49) |  |  |
| Cross-twin-cross-trait correlation | MZ female | 0.20 | (0.13, 0.26) | 3.95 | 0.0001 |
|  | DZ female | 0.07 | (-0.01, 0.14) |  |  |

95% CI = 95% confidence interval

Means and prevalence assumed symmetric between twin 1 and twin 2. Variance of each phenotype was allowed to differ between different twin types. Phenotypic correlation was assumed the same in twin 1 and twin 2. Cross-twin-cross-trait correlation was assumed to be the same between twin 1 and twin 2 as between twin 2 and twin 1.

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Supplementary Material Table 5.

Phenotypic correlations, intra-class correlations, and cross-twin cross-trait correlations for hyperactive-impulsive (HI) and inattentive (IN) ADHD symptoms with binge-eating behavior (BE) in 13,773 female twins (3664 complete twin pairs: 2156 MZ and 1508 DZ pairs), adjusted for age (linear), and males set as missing

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type of correlation |  | Correlation estimate | (95% CI) | Z | p-value |
| **HI and BE** |  |  |  |  |  |
| Phenotypic correlation | MZ female | 0.18 | (0.12, 0.24) | 1.22 | 0.22 |
|  | DZ female | 0.14 | (0.10, 0.18) |  |  |
| Intra-class correlation, HI | MZ female | 0.40 | (0.35, 0.44) | 7.19 | <.0001 |
|  | DZ female | 0.18 | (0.12, 0.24) |  |  |
| Intra-class correlation, BE | MZ female | 0.66 | (0.55, 0.76) | 14.38 | <.0001 |
|  | DZ female | 0.30 | (0.09, 0.49) |  |  |
| Cross-twin-cross-trait correlation | MZ female | 0.16 | (0.10, 0.23) | 3.31 | 0.0009 |
|  | DZ female | 0.05 | (-0.04, 0.12) |  |  |
| **IN and BE** |  |  |  |  |  |
| Phenotypic correlation | MZ female | 0.18 | (0.13, 0.24) | -0.31 | 0.76 |
|  | DZ female | 0.19 | (0.14, 0.23) |  |  |
| Intra-class correlation, IN | MZ female | 0.38 | (0.34, 0.43) | 7.10 | <.0001 |
|  | DZ female | 0.16 | (0.10, 0.22) |  |  |
| Intra-class correlation, BE | MZ female | 0.65 | (0.54, 0.75) | 13.86 | <.0001 |
|  | DZ female | 0.30 | (0.09, 0.49) |  |  |
| Cross-twin-cross-trait correlation | MZ female | 0.17 | (0.11, 0.23) | 3.02 | 0.003 |
|  | DZ female | 0.07 | (-0.01, 0.15) |  |  |

95% CI = 95% confidence interval. Means and prevalence assumed symmetric between twin 1 and twin 2; Variance of each phenotype allowed to differ between different twin types; Phenotypic correlation assumed the same in twin 1 and twin 2; Cross-twin-cross-trait correlation assumed to be the same between twin 1 and twin 2 as between twin 2 and twin 1.

Supplementary Material Table 6.

Distribution of binge-eating behavior (BE) and ADHD symptoms in same sex adult female twins, vs main results.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | A2 | C2 | D2 | E2 | rA | rC | rD | rE | A2 for overlap | C2 for overlap | D2 for overlap | E2 for overlap |
|  |  | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) |
| ACE | ADHD | 0.38  (0.24, 0.47) | 0.05  (0, 0.17) | . | 0.57  (0.53, 0.61) | . | . | . | . | . | . | . | . |
|  | BE | 0.70  (0.45, NA) | 0.003 (NA, 0.24) | . | 0.30  (0.20, NA) | . | . | . | . | . | . | . | . |
|  | Overlap | . | . | . | . | 0.33  (0.07, 0.72) | -1  (NA, 1) | . | 0.10  (-0.04, 0.24) | 0.86  (0.17, 1.56) | -0.06  (-0.64, 0.51) | . | 0.20  (-0.10, NA) |
| ADE | ADHD | 0.43  (0.26, 0.47) | . | 0.01  (0, 0.15) | 0.57  (0.53, 0.60) | . | . | . | . | . | . | . | . |
|  | BE | 0.02  (0, 0.11) | . | 0.71  (0.54, NA) | 0.28  (0.19, NA) | . | . | . | . | . | . | . | . |
|  | Overlap | . | . | . | . | 1  (NA, NA) | . | 1  (NA, NA) | 0.10  (NA, 0.25) | Note 1 | . | . | . |
| AE | ADHD | 0.43  (0.40, 0.47) | . | . | 0.57  (0.53, 0.60) | . | . | . | . | . | . | . | . |
|  | BE | 0.70  (0.57, NA) | . | . | 0.30  (0.20, NA) | . | . | . | . | . | . | . | . |
|  | Overlap | . | . | . | . | 0.28  (0.17, 0.40) | . | . | 0.10  (-0.04, 0.24) | Note 2 |  | . | 0.21  (-0.09, 0.47) |

95%CI = 95%Confidence interval

Note 1: unable to estimate the CI for A2, D2, and E2 of the overlap

Note 2: unable to estimate the CI for A2 of the overlap