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Schilder, Christina M. T.; van Elburg, Annemarie A.; Snellen, Wim M.; Sternheim, Lot C.; Hoek, Hans W.; Danner, Unna N.

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ORIGINAL ARTICLE

Intellectual Functioning of Adolescent and Adult Patients with Eating Disorders

Christina M.T. Schilder, PhD[1,2,3]*
Annemarie A. van Elburg, MD, PhD[1,3,4]
Wim M. Snellen, Msc[2]
Lot C. Sternheim, PhD[3,4]
Hans W. Hoek, MD, PhD[1,3,5,6,7]
Unna N. Danner, PhD[1,3]

ABSTRACT

Objective: Intelligence is a known vulnerability marker in various psychiatric disorders. In eating disorders (ED) intelligence has not been studied thoroughly. Small-scale studies indicate that intelligence levels might be above general population norms, but larger scale studies are lacking. The aim of this study was to determine intellectual functioning in ED patients and associations with severity of the disorder. Methods: Wechsler's Full scale IQ (FSIQ), Verbal IQ (VIQ) and Performance IQ (PIQ) of 703 adolescent and adult ED patients were compared with population norms. Exploratory analyzes were performed on associations between IQ and both somatic severity (BMI and duration of the disorder) and psychological/behavioral severity (Eating Disorder Inventory [EDI-II] ratings) of the ED. Results: Mean IQ's were significantly higher than population means and effect-sizes were small-to-medium ($d = .28$, .16 and .23 for VIQ, PIQ, and FSIQ). No linear associations between IQ and BMI were found, but the most severely underweight adult anorexia nervosa (AN) patients (BMI $\leq$ 15) had higher VIQ (107.7) than the other adult AN patients (VIQ 102.1). In adult AN patients PIQ was associated with psychological/behavioral severity of the ED. Discussion: Our findings suggest that, in contrast with other severe mental disorders where low intelligence is a risk factor, higher than average intelligence might increase the vulnerability to develop an ED.

Keywords: IQ; intelligence; intellectual functioning; eating disorders; anorexia nervosa; bulimia nervosa; vulnerability marker

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Introduction

Over the last decades there has been increasing interest in the study of neuropsychological characteristics of individuals with eating disorders (EDs). Typically, research has centered around specific cognitive functions that are found to be relative weak in ED patients, for example "set shifting" and "central coherence".[1,2] The growing use of such specific cognitive characteristics as vulnerability markers for developing an ED[3,4] raises the issue of whether global measures of cognition, such as general intelligence might also predict vulnerability to develop an ED.

In other psychiatric disorders, general intelligence as a candidate vulnerability marker is more thoroughly evaluated. The extent to which general intelligence serves as a vulnerability marker appears to be dependent on the specific disorder.[5,6] For schizophrenia and severe depression, for example, low intelligence is a known risk factor for development of the disorder, but for bipolar disorder, intelligence is not associated with increased risk.[5,7–10] For EDs, the role of the intelligence level in the development is largely unknown. Recent findings of high IQ in eight-year old children at high risk of an ED suggest that high (and not low) intelligence might increase the vulnerability to develop an ED.[11] Further evidence of high intelligence as a vulnerability marker in ED patients might be derived from a study of Blanz et al.[12] who found a correlation between higher intelligence and the achievement of more weight loss before hospitalization for ED.

Despite this growing interest in (high) intelligence as a possible vulnerability marker for development of EDs, intelligence levels in ED patients

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*Correspondence to: C. M. T. Schilder; E-mail: www.rintveld.nl; www.urge-eatingdisorders.nl
[1] Altrecht Eating Disorders Rintveld, Zeist, The Netherlands
[2] Altrecht Center for Psychodiagnostics, Zeist. The Netherlands
[3] Utrecht Research Group Eating Disorders (URGE), Utrecht University, Utrecht, the Netherlands
[4] Department of Clinical and Health Psychology, Utrecht University, the Netherlands
[5] Parnassia Psychiatric Institute, the Hague, the Netherlands
[6] Department of Psychiatry, Groningen University, the Netherlands
[7] Department of Epidemiology, Columbia University, New York
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are not extensively studied yet. A few studies and one systematic review, predominantly in anorexia nervosa (AN) patients, showed that intelligence levels are as high as, or probably higher than in the general population.[12–16]

Compared to other psychiatric disorders, EDs are unique because of the potential huge impact on the somatic state of the patient and, as a consequence, potential interference with cognitive and intellectual functioning. It is consistently demonstrated that persistent malnutrition in early childhood when significant brain growth and synapse development occurs, has a detrimental effect on intellectual function later in life.[17] Less is known about the effects of malnutrition on cognitive functioning in adolescence. In this sensitive period major developments in particularly the prefrontal cortex take place[18], but this is also a critical period for the onset of EDs. There is some evidence that skipping breakfast has a negative influence on cognitive functioning of adolescents.[19] Studies in adult and elderly patients found associations between deficient vitamin intake and cognitive impairments, suggesting that nutrition is also important for cognitive functioning in adults.[20]

Beside somatic factors, also psychological and behavioral factors such as intruding ED thoughts and concerns, obsessionality, anxiety and depression are associated with cognitive and intellectual performance.[21,22] This suggests that not only the somatic, but also the psychological and behavioral severity of the ED might interfere with intellectual performance.

For this study, intelligence levels of a large sample of currently ill adolescent and adult patients with AN, bulimia nervosa (BN) or eating disorder not otherwise specified (EDNOS) were examined with two aims. The first aim was to test whether intelligence levels are higher than those in the general population. Second, to get insight into the extent to which intelligence is associated with ED severity, associations between IQ and markers for (somatic and psychological/behavioral) severity were studied.

Methods

Study Population and Procedures

Included were all female patients who were referred to Altrecht Eating Disorders Rintveld in Zeist, the Netherlands, and had undergone psychological assessments including the Wechsler Intelligence Scales (third version)[23,24] in the period 2006−2013. Altrecht Eating Disorders Rintveld is a specialist eating disorder service that offers diagnostic assessments, consultation and personalized treatment for in- and outpatients. Rintveld does not apply restrictions regarding the patient's minimum level of intelligence and the age-range is from 6 to 65 years. A psychological assessment was for clinical purposes routinely performed and scheduled shortly after completion of the assessment procedure. The presence of AN, BN or EDNOS was established by ED experts (all medical doctors or clinical psychologists) and confirmed by the Eating Disorder Examination (EDE).[25] Patients who were diagnosed with DSM-IV EDNOS but clinically referred to as AN or BN, and fulfilling DSM-5 AN or BN criteria because they did not fulfill the DSM-IV criteria with respect to amenorrhea (for AN patients) or with respect to frequency of binges or purging behavior (for BN patients), were, for this study, assigned to the AN and BN patient groups respectively; the remaining DSM-IV EDNOS cases were classified as EDNOS, including binge eating disorder, which in DSM-5 is classified as a separate disorder. All study information was retrospectively extracted from the medical files and analyzed anonymously.

Ethics

The Institutional Review Board of Altrecht Mental Health Institute approved the study. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Instruments

Intellectual functioning. Wechsler Intelligence Scales (adjusted for use in the Dutch language and provided with Dutch norms) were used to measure intellectual functioning. For adolescent patients ($\leq$16 years of age), the Wechsler Intelligence Scale for Children, third version (WISC-III)[24] was used. Adult patients ($\geq$16 years) were assessed with the Wechsler Adult Intelligence Scale, third version (WAIS-III).[23] Both Wechsler scales comprise of a number of subtests from which a full scale IQ (FSIQ), a verbal IQ (VIQ) and a performance IQ (PIQ) was derived.

Severity of the disorder. Three measures for severity of the disorder were used. Firstly, the BMI was composed from body height- and weight information, measured by trained staff. For patients $\leq$ 16 years of age, BMI Z-scores (BMI adjusted for age) were calculated, according to the WHO growth charts[26], for other patients the BMI was used. Secondly, duration of the disorder was defined as the number of years between the self-reported age of onset of the ED and the date of the psychological assessment. Thirdly, the Eating Disorder Inventory, second version (EDI-II) was used.[27] This is a reliable and valid

TABLE 1. Sociodemographic and disease severity related information

	Adolescents (WISC-III)			Adults (WAIS-III)		
	AN ($n = 245$)	BN ($n = 11$)	EDNOS ($n = 34$)	AN ($n = 255$)	BN ($n = 86$)	EDNOS ($n = 72$)
Age in yrs (SD)	14.5 (1.4)	15.4 (0.5)	13.8 (2.2)	21.8 (6.0)	24.9 (7.3)	22.1 (7.0)
Range	10 − 17	15 − 16	9 − 16	16 − 53	16 − 43	16 − 44
BMI or Z−score BMI (SD)	−1.80 (1.2)	0.40 (0.49)	−0.02 (2.0)	17.1 (1.8)	23.5 (5.9)	20.3 (4.3)
Range	−5.50 – 0.70	−0.37 − 1.33	−4.05 − 2.66	11.6 − 21.6	18.1 − 62.6	14.1 − 37.5
Disease duration in yrs (SD)	1.4 (1.2)	1. 2.0 (1.8)	2.1 (2.2)	4.6 (5.5)	8.6 (6.9)	6.5 (5.9)
Range	<1 − 6	<1 − 6	<1 − 8	<1 − 37	<1 − 29	1 − 30
Age at onset in yrs (SD)	13.1 (1.5)	13.4 (1.7)	11.9 (2.7)	17.2 (4.3)	16.1 (4.0)	15.7 (5.1)
Range	9 − 16	10 − 15	4 − 16	7 − 42	7 − 32	8 − 40
	AN	BN	EDNOS	AN	BN	EDNOS
Eating Disorder Inventory (EDI−II) total score (SD)	($n = 232$) 296.8 (62.2)	($n = 11$) 364.0 (66.3)	($n = 20$) 241.6 (76.9)	($n = 213$) 322.4 (55.1)	($n = 65$) 352.1 (51.5)	($n = 57$) 327.9 (66.3)
Drive for Thinness (SD)	30.7 (10.8)	37.5 (4.5)	22.1 (12.0)	32.9 (8.4)	31.6 (5.4)	32.5 (10.1)
Bulimia (SD)	11.4 (5.4)	28.7 (6.7)	12.1 (7.7)	15.8 (7.0)	32.1 (6.0)	20.6 (9.6)
Body Dissatisfaction (SD)	40.8 (11.0)	49.6 (5.3)	30.5 (14.9)	40.5 (10.1)	44.9 (8.5)	43.3 (10.4)
Ineffectiveness (SD)	35.6 (10.1)	41.1 (10.7)	28.3 (11.6)	39.2 (9.4)	40.3 (8.8)	39.4 (10.8)
Perfectionism (SD)	19.2 (5.7)	21.2 (4.8)	16.1 (4.5)	21.6 (5.8)	21.6 (6.0)	21.2 (6.0)
Interpersonal Distrust	21.6 (6.0)	25.8 (8.2)	19.8 (7.7)	24.9 (5.9)	24.4 (7.0)	24.2 (7.0)
Interoceptive Awareness (SD)	31.3 (8.6)	38.3 (11.4)	24.7 (7.3)	34.8 (7.9)	38.4 (8.8)	35.5 (10.0)
Maturity Fears (SD)	27.0 (6.2)	27.7 (8.2)	23.5 (5.1)	26.9 (9.1)	26.1 (7.3)	24.8 (7.0)
Asceticism (SD)	26.3 (7.6)	30.6 (6.5)	20.7 (6.9)	29.2 (6.5)	28.5 (5.9)	28.5 (7.0)
Impulse Regulation (SD)	25.4 (7.0)	32.6 (12.1)	21.1 (6.2)	27.8 (6.9)	30.6 (8.0)	28.9 (8.6)
Social Insecurity (SD)	27.0 (6.4)	30.9 (6.4)	23.0 (8.7)	29.2 (5.5)	29.2 (5.6)	29.0 (6.4)

Note. Wisc-III, Wechsler Intelligence Scale for Children, third edition; WAIS-III, Wechsler Adult Intelligence Scale, third edition; AN, Anorexia Nervosa; BN, Bulimia Nervosa; EDNOS, Eating Disorder Not Otherwise Specified; EDI-II, Eating Disorder Inventory, second edition.

91-item multidimensional self-report questionnaire for the assessment of psychological and behavioral characteristics which are typical for EDs. The EDI-II consists of 11 subscales (see Table 1). All questions were answered on a 6-point Likert scale, the questionnaire provides standardized subscale scores. The EDI-II total score was defined as the sum of the subtest scores.[28]

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) 20.0 was used for all analyses. For comparisons of IQ's with normative data one-sample *t*-tests were used. Mean scores of the patient groups were compared with the population means (i.e., 100). Effect sizes were determined by Cohen's d. Comparisons of IQ's between AN, BN, and EDNOS were performed by means of ANOVA. In order to adjust for multiple comparisons, a two-sided p value $< .01$ was required for significance. Associations between disorder severity and IQ's were studied in several ways. First, the predictive value of disorder severity variables with respect to IQ's was determined by multiple linear regression analyses in the adult AN, BN and EDNOS groups and in the adolescent AN group separately. Second, because relationships between BMI and intelligence might not be linear, IQ's of the most severely underweight patients (BMI $\leq$ 15 for adults and *Z*-score BMI $\leq$ -3 for adolescents) were compared with the scores of patients with higher (*Z*-score) BMI's by independent-samples *t*-tests. Third, in the adult AN, BN, and EDNOS groups and in the adolescent AN group, extreme IQ-groups were determined (above average intelligent patients [FSIQ $\geq$ 115] and below average intelligent patients [FSIQ $\leq$ 85] respectively). Independent-samples t-tests were used to compare these groups with respect to the disorder severity variables. Because of the exploratory nature of the analyzes of associations between the severity of the disorder and intelligence, for these analyzes a two-sided p value <0.05 was considered significant.

Results

Sociodemographic and Disorder-Related Information

Table 1 shows sociodemographic and disorder related information. Complete Wechsler Intelligence Scale data of 703 ED patients were available, comprising WISC-III information of 290 adolescents and WAIS-III information of 413 adults (see **Table 1**). (*Z*-score) BMI data were available for all patients, disorder duration data for 286 adolescent and 408 adult patients. EDI-II data were available for 263 adolescent and 335 adult patients.

Intelligence of ED Patients Compared to Normative Data

FSIQ in the entire patient group (103.2; SD 13.6) was on average significantly higher than the normative mean (i.e., 100; SD 15). Mean VIQ (103.8; SD 13.6) and PIQ (102.2; SD 13.9) were also

significantly higher than the norm (see **Table 2**). Effect-sizes were small. A closer look into different age and diagnostic subgroups showed that in the adolescent AN group the mean FSIQ (104.6; SD 15.3) and VIQ (106.3; SD 15.1) were significantly higher than the normative mean, with small-to-medium effect sizes. For adolescent BN and EDNOS patients no significant differences with the norm were found. In the adult AN group, the mean FSIQ (102.9; SD 12.0), VIQ (102.9; SD 12.1) and PIQ (103.3; SD 12.6) were significantly higher than the normative mean. In the adult BN group only the PIQ (104.4; SD 12.9) was significantly higher than the norm. In the adult EDNOS group differences with the normative means did not reach statistical significance (see **Table 2**). Borderline intellectual functioning (IQ $<$ 85) was present in 8.5% of all patients (11.4% of the adolescents [$n = 33$] and 6.5% of the adults [$n = 27$]). See **Figure 1** for the distribution of IQ scores in the entire patient group and the normative group.

Comparison of IQ's Between AN, BN, and EDNOS

No significant difference in FSIQ, VIQ and PIQ was identified between AN, BN and EDNOS patients. A pattern showing relatively low scores for the adolescent EDNOS group compared with the other two adolescent ED groups was found, but group sizes differed substantially and statistical significance was only at trend level (VIQ: $F = 2.9$, $df = 2$, $p = .06$; PIQ: $F = 2.9$, $df = 2$, $p = .06$; FSIQ: $F = 3.4$, $df = 2$, $p = .03$). In the adult ED patients no single significant difference was found in mean IQ between the AN, BN, and EDNOS groups (VIQ: $F = .3$, $df = 2$, $p = .75$; PIQ: $F = .90$, $df = 2$, $p = .41$; FSIQ: $F = .04$, $df = 2$, $p = .96$).

Relationships between Measures of Disorder Severity/Duration and Intelligence

Due to the small sample size of the adolescent BN and EDNOS groups (11 and 34 patients respectively), associations between IQ and measures for severity of the disorder were only investigated in the adolescent AN group and the adult AN, BN, and EDNOS groups.

Only in adult ED patients, and not in adolescents, associations between disorder severity variables and IQ scores were found. In the adult AN group, more severe disorder was associated with lower PIQ and FSIQ. Differences in BMI, disorder duration and EDI-II total score explained 6% of the variance in the PIQ and 3% of the variance in the FSIQ. A closer look revealed that only the EDI-II total score was negatively associated with PIQ and FSIQ. There were no associations between BMI or duration of the disorder and PIQ and FSIQ. In the adult AN group, the most severely underweight patients (BMI $\leq$15, $n = 35$) had significantly higher VIQ (107.7, SD 11.7) than the other adult AN patients (VIQ 102.1; SD 11.9; $n = 220$: $t = 2.6$, $df = 253$, $p = .01$, Cohen's $d = .47$). Such difference was not present in the adolescent AN group: no significant differences in IQ's were present between severely underweight patients (Z-score BMI $\leq$-3, $n = 40$) and the other patients ($n = 205$). In the adult BN and EDNOS groups, the combination of three disorder severity variables (i.e., BMI, duration of the disorder and EDI-II total score) did not explain the variance in IQ scores significantly, but higher BMI was associated with lower VIQ in the BN patients and with lower PIQ in the EDNOS patients (see **Table 3**).

The comparisons of disorder severity variables between extreme IQ groups (above average intelligent patients [IQ $\geq$ 115] versus below average intelligent patients [IQ $\leq$ 85]) pointed, with respect to the EDI-II-total score, in a similar direction as the results of the regression analyzes: the adult AN patients with above average FSIQ ($n = 30$) and PIQ scores ($n = 35$) had significant lower EDI-II total scores than the AN patients with below average FSIQ ($n = 18$) and PIQ scores ($n = 19$). (FSIQ $\leq$ 85: EDI-II-total score 339.50, SD 50.38, FSIQ $\geq$ 115: EDI-II-total score 298.80, SD 56.11, $t = 2.6$, $df = 46$, $p = .01$, Cohen's $d = .76$; PIQ $\leq$ 85: EDI-II-total score 336.84, SD 57.85, FSIQ $\geq$ 115: EDI-II-total score 301.03, SD 55.12, $t = 2.2$, $df = 52$, $p = .03$, Cohen's $d = .63$). In the adult BN and EDNOS groups, as well as in the adolescent AN group, the extreme IQ groups did not differ on disorder severity variables.

Discussion

The results of this study indicate that intelligence levels of female ED patients are on average significantly higher than in the general population. For the entire patient group, effect-sizes were small, but in the adolescent AN and BN group, differences of FSIQ and VIQ with normative data had small-to-medium effect sizes. Similar effect sizes were found in the adolescent and adult BN groups with respect to the PIQ's. Remarkably, the most severely underweight adult AN patients (BMI $\leq$ 15) had significantly higher VIQ than the less underweight adult AN patients. Results of previous intelligence studies in ED patients were inconclusive. Lopez et al.[14] indeed concluded in a systematic review of several

TABLE 2. IQ's of adolescent and adult AN, BN, and EDNOS patients, comparisons with normative data

Adolescents (WISC-III)															
	AN ($n = 245$)					BN ($n = 11$)					EDNOS ($n = 34$)				
	Mean (SD)	T	df	P[b]	Cohen's d[c]	Mean (SD)	t	df	P[b]	Cohen's d[c]	Mean (SD)	t	df	P[b]	Cohen's d[c]
Verbal IQ[a]	106.3 (15.1)	6.5	244	<0.001	0.42	105.3 (11.4)	1.5	10	0.16	0.46	99.6 (17.2)	−0.15	33	0.88	−0.02
Range	65-145					88-128					60-132				
Performance IQ[a]	101.3 (15.4)	1.3	244	0.20	0.08	104.6 (7.8)	1.9	10	0.08	0.59	95.0 (15.4)	−1.9	33	0.07	−0.32
Range	58-139					89-113					68-126				
Full scale IQ[a]	104.6 (15.3)	4.7	244	<0.001	0.30	105.4 (7.4)	2.4	10	0.04	0.73	97.4 (16.6)	−0.9	33	0.36	−0.16
Range	68-145					97-121					61-133				
Adults (WAIS-III)															
	AN ($n = 255$)					BN ($n = 86$)					EDNOS ($n = 72$)				
	Mean (SD)	t	df	P[b]	Cohen's d[c]	Mean (SD)	t	df	P[b]	Cohen's d[c]	Mean (SD)	t	df	P[b]	Cohen's d[c]
Verbal IQ[a]	102.9 (12.0)	3.8	254	<0.001	0.24	101.9 (11.3)	1.5	85	0.13	0.17	103.1 (13.1)	2.0	71	0.05	0.23
Range	67-133					77-131					75-128				
Performance IQ[a]	103.3 (12.6)	4.1	254	<0.001	0.26	104.4 (12.9)	3.2	85	0.002	0.34	101.7 (12.7)	1.1	71	0.26	0.13
Range	62-140					77-130					72-129				
Full Scale IQ[a]	102.9 (12.1)	3.8	254	<0.001	0.24	102.7 (12.1)	2.1	85	0.04	0.22	102.5 (13.1)	1.6	71	0.12	0.19
Range	72-133					77-131					77-131				
All patients combined (N = 703)															
	Mean (SD)		t		df	P[b]				Cohen's d[c]					
Verbal IQ[a]	103.8 (13.6)		7.5		702	<0.001				0.28					
Range	60-145														
Performance IQ[a]	102.2 (13.9)		4.1		702	<0.001				0.16					
Range	58-147														
Full scale IQ[a]	103.2 (13.6)		6.2		702	<0.001				0.23					
Range	61-145														

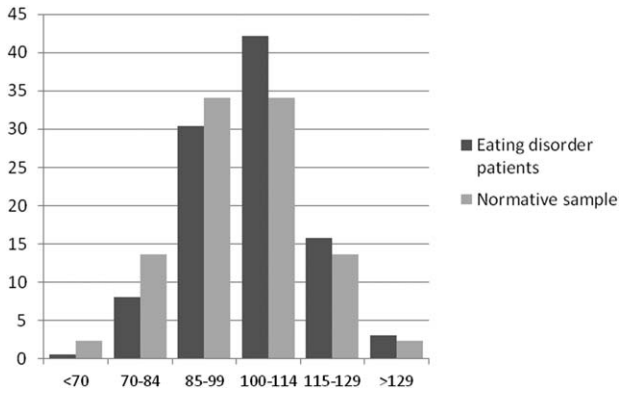
Note. Wisc-III, Wechsler Intelligence Scale for Children, third edition; WAIS-III, Wechsler Adult Intelligence Scale, third edition; AN, Anorexia Nervosa; BN, Bulimia Nervosa; EDNOS, Eating Disorder Not Otherwise Specified.

[a]Population mean = 100, standard deviation = 15.

[b]*p* values of the comparison with the normative mean.

[c]0.2 = small, 0.5 = medium, 0.8 = large.

FIGURE 1. Distribution (percentages) of Full Scale IQ scores in the entire patient group and normative data.



small studies ($n = 10$–98) that AN patients had higher than average intelligence levels, but observed high variability between studies. Recent studies also showed variable results. In a small study, borderline intelligence levels were seen in severe restricting-type AN patients[29] but Weider et al.[15] found average intelligence levels in AN patients but higher intelligence levels in BN patients (especially with respect to PIQ) shortly after admission to full-time care. Kjaersdam Telleus et al.[16] found, in adolescent AN patients, FSIQ close to normal, but significantly worse PIQ compared to a healthy control group. As intelligence is strongly associated with education levels[30], our findings might reflect higher than average education levels of ED patients. Family history in education is an established risk factor for ED.[31] We did not find any difference in IQ between the AN, BN and EDNOS groups. Therefore, it is unlikely that AN, BN and EDNOS have clear distinct intelligence levels. Only a few studies reported on IQ differences between categories of ED, but also these results were inconclusive. In two studies[12,13] no IQ differences between AN and BN were found, but Weider et al.[15] found significantly higher PIQ in BN patients compared to AN patients.

Our finding that intelligence levels in ED patients are above the norm suggests that, for women, higher than average intelligence might be one of the factors that increase vulnerability for developing an ED. This supports the findings of Kothari et al.[11] who found high PIQ and FSIQ in 8-years old children at high risk of an ED. Previous studies already showed that the extent to which intelligence serves as a vulnerability marker for psychiatric disorders is dependent on the specific disorder.[5,6] Our study contributes to that knowledge by suggesting that higher than average intelligence might serve as a vulnerability marker for development of an ED.

In adult AN patients, the PIQ is associated with the psychological/behavioral severity of the ED. Because the EDI-II-total score is an aggregation of very different aspects of ED symptomatology the explanation of this finding is not immediately clear, but it provides indications that that more severity of symptoms such as body dissatisfaction, drive for thinness and impulse regulation problems is associated with lower PIQ scores. Until now, relationships between psychological/behavioral severity of EDs and intellectual functioning are hardly studied, but our results are in line with the small study of Koyama et al.[29] that also showed negative correlations between EDI-II scores and WAIS-III scores.

Interestingly, no linear associations were found between (Z-score) BMI and IQ. This indicates that low BMI does not interfere with reliable intelligence measurement. In spite of the knowledge about the importance of good nutrition for intellectual functioning, most other studies in ED patients also failed to find relationships between BMI and intellectual functioning in ED patients.[14] An exception is the study of Koyama et al.[29] who found significant correlations between lower BMI and lower IQ in severe restricting-type AN patients. With respect to verbal abilities, our results even suggest associations in the opposite direction, as we found higher VIQ in the adult AN patients with the lowest BMI ($\leq$15) compared to the other adult AN patients. This finding suggests that the AN patients with the better verbal capacities might have a greater risk of extreme weight loss. Evidence for this idea is provided earlier by Blanz et al.[12] who found an association between higher intelligence and more weight loss before hospitalization in AN patients.

A potential factor that plays a role in the lack of association between (Z-score) BMI and intelligence might be that current (Z-score) BMI does not provide sufficient information about the somatic severity of the ED as patients with similar BMI's might differ substantially in overall somatic condition.[32] Future research should focus on determining better measures for the somatic severity of the ED. Interestingly, in this respect, Weider et al.[15] suggested that not current BMI, but lowest BMI ever is associated with particular subtests of the PIQ.

Strengths of this study are the large sample size ($n = 703$), the use of comprehensive and widely internationally used intelligence tests and the inclusion of AN, BN and EDNOS groups. A limitation is

TABLE 3. Predicting value of variables for disease severity on IQ's for adolescent and adult AN patients and adult BN and EDNOS patients

	Adolescents AN ($n = 223$)				AN ($n = 211$)				Adults BN ($n = 64$)				EDNOS ($n = 54$)			
Verbal IQ																
Model	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*
	−0.01	0.20	222	0.90	0.01	1.46	210	0.23	0.05	2.04	63	0.12	−0.02	0.61	53	0.62
Predictors	*B*	*t*	*p*		β	*t*	*p*		β	*t*	*p*		β	*t*	*p*	
(Z−score) BMI	0.02	0.24	0.81		−0.08	−1.18	0.24		−0.26	−2.10	0.04		−0.19	−1.34	0.19	
disease duration	−0.02	0.35	0.81		−0.07	−0.97	0.34		0.16	1.30	0.20		−0.01	−0.06	0.96	
EDI−II total score	−0.05	0.65	0.52		−0.09	−1.30	0.20		0.06	0.48	0.64		−0.002	−0.01	0.99	
Performance IQ																
Model	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*
	0.005	1.41	222	0.24	0.06	5.55	210	0.001	0.03	1.72	63	0.17	0.08	2.53	53	0.07
Predictors	β	*t*	*p*		β	*t*	*p*		β	*t*	*p*		*B*	*t*	*p*	
(Z−score) BMI	0.10	1.50	0.14		0.01	0.21	0.83		−0.19	−1.53	0.13		−0.31	−2.32	0.02	
disease duration	−0.08	−1.22	0.22		−0.05	−0.81	0.42		0.20	1.64	0.11		−0.20	−1.46	0.15	
EDI−II total score	−0.05	−0.68	0.55		−0.27	−4,01	<0.001		0.08	0.65	0.52		−0.01	−0.05	0.96	
Full Scale IQ																
Model	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*	R^2 *adj.*	*Overall F*	*df*	*p model*
	−0.004	0.74	222	0.53	0.03	3.08	210	0.03	0.05	2.15	63	0.10	0.02	1.31	53	0.28
Predictors	β	*t*	*p*		β	*t*	*p*		β	*t*	*p*		β	*t*	*p*	
(Z−score) BMI	0.06	0.90	0.37		−0.04	−0.56	0.58		−0.24	−1.20	0.05		−0.26	−1.86	0.07	
disease duration	−0.06	−0.91	0.36		−0.08	−1.11	0.27		0.20	1.60	0.12		−0.10	−0.70	0.49	
EDI−II total score	−0.05	−0.78	0.44		−0.19	−2.72	0.007		0.06	0.50	0.62		0.004	0.03	0.98	

Note. AN, anorexia nervosa; BN, bulimia nervosa; EDNOS, eating disorder not otherwise specified; BMI, body mass index; EDI−II, Eating Disorder Inventory, second edition.

that our groups of adolescent BN and EDNOS patients were small. Explanations for these small group sizes might include the relative low prevalence of BN relative tot AN in patients $\leq$ 16 year of age[33] and the assignment of EDNOS patients according to DSM-IV criteria to the AN and BN groups in case they met DSM-5 criteria of AN or BN. Another limitation is that we studied intelligence in patients who received treatment for their ED, so we cannot exclude the possibility of socioeconomic biases in the probability of seeking or accessing healthcare. However, there are several reasons that reduce the probability that such bias explains our findings. First, Altrecht Eating Disorders Rintveld does not apply restrictions to the patient's minimum level of intelligence. Second, in the Netherlands patients have easy access to health services.[34] Third, British and Swedish studies provided evidence that socio-economic variables did not predict referral patterns and acceptances in those countries[31,35] and in the Netherlands, the number of referrals to psychiatric care is even relatively high compared to other European countries.[36] Fourth, such bias cannot explain the higher VIQ in particularly the adult AN patients with the lowest BMI. A third limitation of this study is the cross-sectional nature which precluded any conclusions regarding causal relationships between variables. Future longitudinal studies on intelligence, including persons at risk for an ED, currently ill patients and (somatically and psychologically) recovered patients can provide more insight in the value of IQ as a vulnerability marker, and associations with the severity of the disorder.

Apart from the value of intelligence as a vulnerability marker for psychiatric disorders, intelligence is an important predictor for outcome after treatment. For example, in schizophrenia patients, low intelligence predicts worse outcome after treatment.[37] In children and adolescents, higher PIQ is found to be associated with steeper improvement slopes after psychotherapy for various mental health problems.[38] For ED patients, little is known about the role of intelligence in treatment success and outcome. An old study in AN patients showed that neuropsychological status, measured with a test battery that partly consisted of Wechsler Intelligence Scale subtests, was associated with weight restoration.[39] More research is needed to answer questions about the predictive value of intelligence for treatment outcome of ED patients.

In conclusion, our study results show that intelligence in ED patients is higher than general population norms. Effect-sizes are small in adult patients, but are small-to-medium in adolescent AN and BN patients regarding FSIQ and VIQ. This suggest that higher than average intelligence might serve as a vulnerability marker for developing an ED. However, although differences are highly significant, effect-sizes are generally small or small-to-medium, limiting our possibilities to draw strong conclusions. As lower BMI was not associated with lower intelligence scores, low BMI does not interfere with reliable intelligence assessment. In adult AN patients, our results even suggest an inverse relationship between verbal intelligence and BMI as we found that the patients with the lowest BMI ($\leq$ 15) have higher VIQ than the other AN patients. More severe psychological/behavioral ED symptoms were associated with lower FSIQ and PIQ in adult AN patients.

All findings taken together suggest that higher than average intelligence might increase the vulnerability for developing an ED, but might at the same time serve as a protective factor from severe psychological/behavioral symptoms for patients actually suffering from an ED. Alternatively, in ED patients the presence of severe psychological/behavioral symptoms might negatively influence aspects of intellectual functioning, especially in the performance domain. Future longitudinal studies are needed, not only to further investigate the role of intelligence as a vulnerability marker for development of an ED, but also for determination of the predictive value of intelligence for treatment outcome.

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