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Sex/gender differences in the level and variability of autistic traits: a meta-analysis of the Autism-Spectrum Quotient

BACKGROUND
The objective of this meta-analysis was to assess the influence of sex/gender on the level and variability of autistic traits in both autistic and neurotypical samples.

PARTICIPANTS AND PROCEDURE
A systematic search was conducted in the PubMed and EBSCOhost databases in April and May 2019 as well as September 2020. Studies were included if they contained information about mean (*M*) and standard deviation (*SD*) statistics of the Autism-Spectrum Quotient in a group with autism and typically developing participants. Calculations were performed using a random-effects model with study subgroups as the unit of analysis.

RESULTS
A total of 307 articles were chosen for further analysis with 634 786 participants in the studies evaluating the effect of sex/gender on the level of autistic traits and 495 840 individuals in the analyses examining the effect of sex/gender on the variability of autistic traits. Sex/gender moderated mainly the level of total autistic traits score (Q = 22.34, $p \leq .001$) in that the level became higher as more males/men were included in the study but only in the neurotypical sample. The variability was higher in males/men than in females/women in the total level of autistic traits, social behaviors/social skills, communication/mindreading, attention to details/patterns, and attention switching/tolerance of change in a clinical and a non-clinical group of women (from variance =1.65, Q = 59, I^2 = 61.02, τ^2 = 360.20 to variance = 56.69, Q = 47.19, I^2 = 59.22, τ^2 = 8719.17). Furthermore, the impact of sex/gender on the level and variability of autistic traits was more pronounced in the neurotypical group than in the autism sample.

CONCLUSIONS
These findings suggest that males/men tend to display more pronounced and varied autistic traits than females/women. Further research is necessary to gain a better understanding of the scope and nature of these sex/gender differences.

KEY WORDS
autism spectrum quotient; autism; neurodevelopmental disorders; sex/gender differences

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AUTHORS' CONTRIBUTIONS – A: Study design · B: Data collection · C: Statistical analysis · D: Data interpretation · E: Manuscript preparation · F: Literature search · G: Funds collection

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BACKGROUND

Autism spectrum disorders (ASDs) encompass a group of complex neurodevelopmental conditions that emerge in infancy, characterized by challenges in social interactions, communication, affect, and the presence of repetitive and rigid patterns of behavior and interests (APA, 2013). Recent prevalence estimates indicate that ASD affects approximately 1-2% of the population (Kim et al., 2011; Maenner et al., 2021). Despite extensive research, there remains significant controversy surrounding the conceptualization of autism. Some researchers define autistic traits as symptoms exclusive to individuals with neurodevelopmental disabilities (Frazier et al., 2010, 2012, 2014). However, numerous studies have demonstrated that other groups, such as relatives of individuals with ASD, may also exhibit autistic characteristics that do not meet the criteria for an autism diagnosis. Consequently, the construct of autistic-like traits captures subclinical, continuously distributed autistic traits within the general population (Constantino & Todd, 2003; Ronald et al., 2006). Thus, autistic-like traits may manifest across various groups, extending beyond autistic individuals (Baron-Cohen et al., 2001; Constantino & Todd, 2003; Ingersoll & Wainer, 2014). Notably, shared genetic processes have been observed between individuals with an autism diagnosis and those with autistic-like traits, suggesting a degree of common etiology between these constructs (Lundström et al., 2012; Ronald et al., 2006; Ronald & Hoekstra, 2011). However, the relationship between autistic-like traits and temperament remains uncertain, raising doubts regarding whether autistic features in the general population and individuals with an autism diagnosis can be considered part of the same theoretical construct (Omelańczuk & Pisula, 2020). Therefore, it is important to continue studying autistic features in both clinical and non-clinical populations, considering additional factors.

Furthermore, autism is observed across all racial, ethnic, and socioeconomic groups, although it is consistently more prevalent in males than females (Maenner et al., 2021; Zeidan et al., 2022)[1]. These differences may arise from variations in the expression of autistic traits in females that do not align with established diagnostic criteria and assessment tools (Begiatto et al., 2017; Bourson & Prevost, 2022; Rivet & Matson, 2011; Torske et al., 2023). Such sex/gender differences may also be associated with increased camouflaging in females, referring to strategies employed to appear less autistic (Bargiela et al., 2016; Cook et al., 2021; Hull et al., 2020; Wood-Downie et al., 2021). Considering the distribution of ASD across sexes/genders, it is worth examining the classic "greater male variability hypothesis" (GMVH) in this context (Ellis, 1934/1984). Derived from evolutionary Darwinian theory, this hypothesis posits that many biological dimensions exhibit distributions where males are overrepresented at the extremes compared to females. Despite criticisms dating back to the early 1980s, the GMVH hypothesis continues to be discussed and investigated (Baye & Monsieur, 2016; Hedges & Nowell, 1995; Karwowski et al., 2016; Lehre et al., 2009; Taylor & Barbot, 2021). Presently, robust evidence supports the notion of greater male variability in cortical surface area, subcortical volumetric measures, and the majority of cortical thickness measures. These differences may have an effect on many psychological dimensions including autistic traits (Wierenga et al., 2018, 2022). Thus, better understanding of these differences may increase the efficacy of diagnosis and treatment of autistic features.

The Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) is a widely used screening tool for quantifying autistic traits. Originally developed as a self-report measure for adults, it was later adapted as a parent-report instrument for adolescents and children (Auyeung et al., 2008; Baron-Cohen et al., 2001, 2006). The AQ assesses various dimensions of autistic traits, including (1) communication/mind-reading, reflecting impairments in verbal or non-verbal mindreading and communication, (2) social skills, describing difficulties with verbal or non-verbal social interaction, (3) attention to detail, defined as a tendency to focus on details while neglecting the "big picture," (4) attention switching/tolerance of change, reflecting focused, intense, and repetitive behavior patterns, and (5) imagination, describing reduced abstraction and creativity.

Despite the extensive research on autism, only a few studies have conducted meta-analyses to investigate the impact of sex/gender on the level of autistic traits. For instance, Loomes et al. (2017) estimated the male-to-female ratio in individuals diagnosed with autism based on Diagnostic and Statistical Manual of Mental Disorders (DSM; APA, 1994, 2000) criteria and International Classification of Diseases 10th Revision (ICD-10; WHO, 1992) criteria. Another study by Van Wijngaarden-Cremers et al. (2014) examined sex/gender differences in core autistic traits using various assessment instruments, finding differences in repetitive and stereotyped behaviors between males and females with autism. In a different study, Ruzich et al. (2015) analyzed the effect of sex/gender on autistic traits in nonclinical and clinical populations. They observed a sex/gender difference in the level of autistic traits in non-clinical participants but not in the clinical group. The AQ scores demonstrated good internal consistency, test-retest reliability, and validity in previous research (Auyeung et al., 2008; Baron-Cohen et al., 2001, 2006). The AQ's multidimensional nature further allows for potential differences in autistic trait profiles between

females and males (Van Wijngaarden-Cremers et al., 2014) and across clinical and non-clinical populations (Ruzich et al., 2015).

Thus, there is a gap in the literature. This meta-analysis will significantly extend our current knowledge as this will be the first study to comprehensively examine sex/gender differences in the level of various core autistic traits as well as evaluating sex/gender differences in the variability of many core autistic symptoms. Additionally, by investigating these differences across clinical and non-clinical populations, this study will provide a more comprehensive understanding of sex/gender effects on autistic traits, shedding light on unexplored aspects of this complex phenomenon.

CURRENT STUDY

In this study, we have undertaken a comprehensive examination of the influence of sex/gender on the level and dispersion of autistic traits. The primary objective of our study was to assess whether the effect of sex/gender on the level and dispersion of autistic characteristics varies between clinical populations (comprising individuals diagnosed with ASD) and non-clinical cohorts (comprising neurotypical individuals without any developmental or psychiatric disorders). Our specific research inquiries encompassed the following: (1) the association between sex/gender and the level of autistic traits, (2) potential distinctions in the impact of sex/gender on the level of autistic traits between individuals in an autistic sample and those in a neurotypical sample, (3) disparities in the variability of autistic traits across genders, and (4) potential discrepancies in the effect of sex/gender on the variability of autistic traits within autistic and neurotypical groups.

PARTICIPANTS AND PROCEDURE

INFORMATION SOURCES

To identify the most valid databases for our searches and gain broad access to articles beyond those indexed in the JCR list, we initially performed pilot searches using the phrase "Autism Spectrum Quotient" in the main psychological search engines (PubMed, ProQuest, Academic Search Complete EBSCOhost, Web of Science, and Ovid). In April and May 2019, as well as September 2020, we searched the PubMed and EBSCOhost search engines using the keywords "Autism Spectrum Quotient" as they showed the highest relevance to our field of interest and provided access to full-text articles. The searches in April and May 2019 encompassed the earliest records up to the end of May 2019. The searches in September 2020 encompassed studies from the beginning of June 2019 to the end of September 2020.

INCLUSION AND EXCLUSION CRITERIA

To be included in this meta-analysis, articles had to meet the following criteria: (1) the study used the long or short version of the Autism-Spectrum Quotient in any language, (2) mean (*M*) and standard deviation (*SD*) statistics were reported, (3) the sample included children and adults, (4) the study provided information on the exact number of male and female participants, (5) the study included either autism or neurotypical samples, and (6) the article was a research-type article. Studies were excluded if (1) the Autism-Spectrum Quotient scales were not based on the original scale construction (i.e., created by factor loading analysis), (2) the participants were not a typically developing sample or an ASD group, or (3) the study was a meta-analysis or review.

DATA EXTRACTION

The data selection and coding process were carried out by a doctoral level psychologist who was trained and supervised by an expert experienced in conducting meta-analyses. Studies were searched in EBSCOhost and PubMed databases. All of them were initially evaluated at the title and abstract level. Studies which might meet our meta-analysis criteria were downloaded and reviewed manually. Next, the data of studies were coded if they met basic inclusion and exclusion criteria. The accuracy of 25% of the coded data was checked by an expert by random selection. Information on the number of male and female participants, group type, and M and SD for the total AQ score and sub-scale scores was extracted from the studies.

STATISTICAL ANALYSES

The *M* was used to assess the level of autistic traits, while the *SD* was used to evaluate variability. In this meta-analysis, only one *M* and *SD* for each group within a study were used in the data coding process for each outcome (total AQ score and sub-scale scores). A convergent data selection process was performed based on the effect size level and the number of participants in this meta-analysis (López-López et al., 2018). There were no duplicates in the data file. Calculations were conducted using a random-effects model with study subgroups as the unit of analysis. Heterogeneity was assessed using measures such as the *Q* statistic (Cochran, 1954; Hedges & Olkin, 1985), which reflects the total variance in the study, as well as I^2 (Higgins

et al., 2003) and τ^2 (Thompson & Sharp, 1999), which represent heterogeneity between the studies.

Additionally, we performed publication bias and selective reporting analyses in this meta-analysis. To evaluate whether the findings of this meta-analysis were influenced by the file-drawer problem (i.e., the tendency to publish results with statistically significant effects and not publish studies with non-significant effects), we used Rosenthal's fail-safe *N* (Rosenthal, 1979, 1995). We also conducted Egger's test for bias (Egger et al., 1997) to examine whether the meta-analysis results were influenced by small-study effects, which refers to the phenomenon that smaller studies may produce different effects than larger studies (Sterne et al., 2000). Finally, we performed trim and fill (Duval & Tweedie, 2000) random-effects model analysis to adjust for any asymmetry in funnel plots and generate "missing" effect sizes until the plots became symmetrical, thus addressing relationships at risk for publication bias.

The analyses were conducted using Comprehensive Meta-Analysis Software version 3.0 for Windows.

RESULTS

STUDY CHARACTERISTICS

A total of 3,376 records were identified (2,155 in PubMed and 1,221 in EBSCOhost). At the title and abstract level, 2,166 studies were excluded. At the full-text level, 1,210 articles (1,094 from April and May 2019 and an additional 116 articles from September 2020) were downloaded and reviewed. Of these, 905 studies were excluded for various reasons. Finally, 307 articles were selected (289 in PubMed and 18 in EBSCOhost) for further analysis with a total of 634 786 participants in the studies evaluating the effect of sex/gender at the level of autistic traits and 495 840 individuals (65.10% female participants and 34.90% male participants) in the analyses examining the effect of sex/gender on the variability of autistic traits (see Figure 1).

Total scores were examined in 555 and 147 samples, social behaviors/social skills in 203 and 70 groups, communication/mindreading in 190 and 67 samples, attention to details/patterns in 206 and 70 groups, attention switching/tolerance of change in 196 and 67 samples, and imagination in 187 and 65 groups in the studies evaluating the effect of sex/gender on the level and variability of autistic traits, respectively. The age of participants ranged from 18 to 70.10 years old. In all of the studies, the AQ was self-reported. In 295 cases (96.10%) the English version of the AQ was used, and in 12 studies (3.90%), other language versions of the AQ were used, such as Dutch, Chinese, Japanese, Korean, Norwegian, Spanish, and Polish. In 284 studies (92.53%) the long version of the AQ (including 50 items) was used and in 23 cases (7.47%), other versions of the AQ were used, such as 28-item versions in 13 studies (4.23%), 10-item versions in 7 studies (2.28%), 16 items in 1 study (0.32%), 25 items in 1 study (0.32%), and 39 items in 1 study (0.32%).

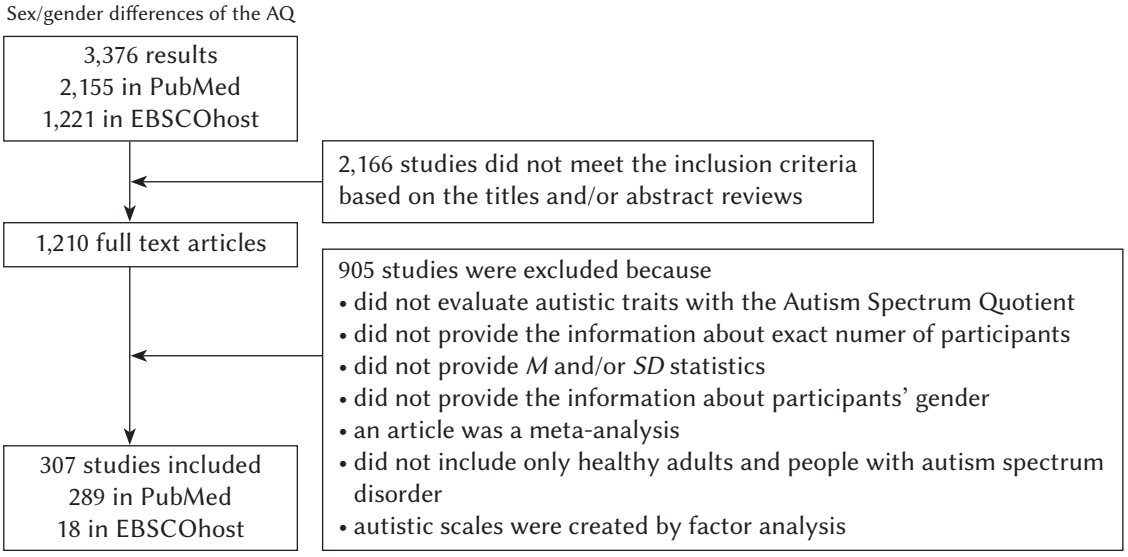
MAIN RESULTS

The main results of the heterogeneity analyses for the autistic traits are presented in Table 1.

Significant heterogeneity was found: (1) for the total score, social behaviors/social skills, communication/mindreading, attention to details/patterns, at-

Figure 1

Literature selection process



tention switching/tolerance of change, and imagination scales (from Q = 3697.14, $p \leq .001$, to 51917.22, $p \leq .001$; from I^2 = 99.16% to I^2 = 99.80%; from τ^2 = 16.39 to τ^2 = 336.10) in the ASD sample, and (2) for the total score, social behaviors/social skills, communication/mindreading, attention to details/patterns, attention switching/tolerance of change, and imagination scales (from Q = 140171.61, $p \leq .001$, to 4151998.21, $p \leq .001$; from I^2 = 99.51% to I^2 = 99.99%; from τ^2 = 7.21 to τ^2 = 18.59) in the typically developing sample.

Effect of sex/gender on the level of autistic traits. The main results for the effect of sex/gender on the level of autistic traits are presented in Table 2.

Sex/gender moderated the level of total autistic traits score (Q = 22.34, $p \leq .001$, R^2 = 0%) and imagination (Q = 7.00, $p \leq .01$, R^2 = 0%) in that the level of these dimensions became higher as more males/men were included in the study in the neurotypical sample. No significant effect was found in the clinical group.

Effect of sex/gender on the variability of autistic traits. The main results for the effect of sex/gender on the variability of autistic traits are presented in Table 3.

There were significant differences in variability between males/men and females/women: (1) in the total level of autistic traits, social behaviors/social skills, communication/mindreading, attention to details/patterns, and attention switching/tolerance of change, in that the variability was higher in males/men (from variance = 4.94, Q = 17.64, I^2 = 31.96, τ^2 = 421.77 to variance = 56.69, Q = 47.19, I^2 = 59.22, τ^2 = 8719.17) than in females/women (from variance = 1.80, Q = 6.97, I^2 = 28.23, τ^2 = 175.74 to variance = 30.99, Q = 20.33, I^2 = 52.55, τ^2 = 5449.48) in the ASD sample, and (2) in the total level of autistic traits, social behaviors/social skills, communication/mindreading, attention to details/patterns, attention switching/tolerance of change, and imagination, in

Table 1

Heterogeneity analyses for autistic traits

	Subgroup	Mean	*SE*	95% CI	*Z*	*k*	*Q*	I^2	τ^2
Total score	Total sample	31.91	0.13	[31.66; 32.15]	255.86*	555	4381752.29*	99.99%	7.60
	ASD sample	45.43	1.79	[41.92; 48.93]	25.42*	106	51917.22*	99.80%	336.10
	Non-clinical sample	29.49	0.13	[29.23; 29.75]	220.45*	449	4151998.21*	99.99%	7.21
Social behaviors/ social skills	Total sample	9.72	0.31	[9.12; 10.32]	31.81*	203	218123.51*	99.91%	18.71
	ASD sample	13.23	0.98	[11.31; 15.14]	13.55*	36	11901.45*	99.71%	33.93
	Non-clinical sample	8.99	0.34	[8.34; 9.65]	26.79*	167	204895.16*	99.92%	18.59
Communication/ mindreading	Total sample	6.75	0.27	[6.22; 7.28]	24.89*	190	182957.17*	99.90%	13.83
	ASD sample	10.09	0.72	[8.67; 11.50]	13.96*	32	3697.14*	99.16%	16.39
	Non-clinical sample	6.09	0.29	[5.51; 6.66]	20.73*	158	175223.41*	99.91%	13.51
Attention to details/ patterns	Total sample	8.74	0.25	[8.24; 9.24]	34.47*	206	158755.80*	99.87%	13.06
	ASD sample	9.62	0.77	[8.10; 11.13]	12.42*	36	7115.03*	99.51%	21.28
	Non-clinical sample	8.56	0.28	[8.02; 9.11]	30.78*	170	151449.08*	99.89%	13.01
Attention switching/ tolerance of change	Total sample	8.01	0.23	[7.57; 8.46]	35.22*	196	174100.12*	99.89%	9.90
	ASD sample	10.91	0.78	[9.39; 12.44]	14.03*	36	11778.89*	99.70%	21.54
	Non-clinical sample	7.39	0.25	[6.90; 7.88]	29.54*	160	161942.68*	99.90%	9.86
Imagination	Total sample	6.92	0.23	[6.46; 7.38]	29.61*	187	148068.58*	99.87%	10.06
	ASD sample	9.82	0.75	[8.35; 11.29]	13.11*	35	7739.54*	99.56%	19.35
	Non-clinical sample	6.28	0.26	[5.78; 6.79]	24.37*	152	140171.61*	99.89%	9.98

Note. ASD – autism spectrum disorder; *SE* – standard error; CI – confidence interval of the effect sizes; *Z* – significance test; *k* – number of effect sizes; *Q* – total variance; I^2 and τ^2 – between-study variance; *$p \leq .001$.

that the variability was higher in males (from variance = 1.36, Q = 50.70, I^2 = 52.66, τ^2 = 164.19 to variance = 65.42, Q = 375.44, I^2 = 88.47, τ^2 = 8102.77) than in females (from variance = 0.98, Q = 50.77, I^2 = 52.10, τ^2 = 250.90 to variance = 96.41, Q = 419.87, I^2 = 86.01, τ^2 = 8408.54) in the typically developing sample.

PUBLICATION BIAS

Publication bias analyses are presented in Table 4.

Only Egger's test (Egger et al., 1997) for bias showed a significant publication bias for all of the examined outcomes. Thus, all the outcomes were adjusted with trim and fill random effect model analyses (Duval & Tweedie, 2000). These analyses indicated that from 2 to 111 studies were "missing" on the right side of the funnel plot. The study results were underestimated. Thus, estimates increased after including these "missing" effect sizes.

DISCUSSION

MAIN FINDINGS

This study aimed to assess the impact of sex/gender on the level and variability of autistic traits. Out of the 1,210 articles initially identified, 307 studies met the inclusion criteria. The analyses were conducted using mean (*M*) and standard deviation (*SD*) data. The results revealed a significant effect of sex/gender on the level of autistic traits. In the typically developing sample, as the number of males increased, the level of total autistic traits and imagination scores also increased. However, this effect was not observed in the autis-

Table 2

Effect of gender on the level of autistic traits

Outcome	Subgroup	β, *SE*, *Z*, *k*, CI	*Q*	R^2
Total score	Total sample	β = .06, *SE* = .01, *Z* = 7.63, *k* = 555, 95% CI [.043; .073]	58.27***	.00
	ASD sample	β = .02, *SE* = .01, *Z* = 0.34, *k* = 106, 95% CI [−.085; .120]	0.12	.00
	Non-clinical sample	β = .04, *SE* = .01, *Z* = 4.72, *k* = 449, 95% CI [.023; .056]	22.24***	00
Social behaviors/ social skills	Total sample	β = .02, *SE* = .01, *Z* = 1.74, *k* = 203, 95% CI [−.002; .031]	3.01	.00
	ASD sample	β = −.02, *SE* = .03, *Z* = −0.91, *k* = 36, 95% CI [−.007; .028]	0.83	.00
	Non-clinical sample	β = .02, *SE* = .01, *Z* = 1.60, *k* = 167, 95% CI [−.003; .034]	2.55	.00
Communication/ mindreading	Total sample	β = .01, *SE* = .01, *Z* = 1.68, *k* = 190, 95% CI [−.002; .027]	2.82	.00
	ASD sample	β = −.02, *SE* = .02, *Z* = −0.79, *k* = 32, 95% CI [−.053; .023]	0.62	.00
	Non-clinical sample	β = .01, *SE* = .01, *Z* = 1.30, *k* = 158, 95% CI [−.005; .026]	1.69	.00
Attention to details/ patterns	Total sample	β = .01, *SE* = .01, *Z* = 0.75, *k* = 206, 95% CI [−.008; .019]	0.56	.00
	ASD sample	β = −.02, *SE* = .02, *Z* = −0.71, *k* = 36, 95% CI [−.055; .026]	0.50	.02
	Non-clinical sample	β = .01, *SE* = .01, *Z* = 0.97, *k* = 170, 95% CI [−.008; .023]	0.94	.00
Attention switching/ tolerance of change	Total sample	β = .02, *SE* = .01, *Z* = 2.36, *k* = 196, 95% CI [.000; .027]	5.99*	.00
	ASD sample	β = −.01, *SE* = .02, *Z* = −0.43, *k* = 36, 95% CI [−.049; .031]	0.18	.03
	Non-clinical sample	β = .01, *SE* = .01, *Z* = 1.93, *k* = 160, 95% CI [−.000; .028]	3.73	.00
Imagination	Total sample	β = .02, *SE* = .01, *Z* = 2.93, *k* = 187, 95% CI [.006; .031]	8.61**	.00
	ASD sample	β = −.01, *SE* = .02, *Z* = −0.60, *k* = 35, 95% CI [−.052; .028]	0.36	.00
	Non-clinical sample	β = .02, *SE* = .01, *Z* = 2.65, *k* = 152, 95% CI [.005; .033]	7.00**	.00

Note. ASD – autism spectrum disorder; β – standardized regression coefficient; *SE* – standard error; *Z* – Z value (β/SE); CI – confidence interval; *k* – number of effect sizes, *Q* – test of between-group variance differences; R^2 – coefficient of determination; $^*p \le .05$, $^{**}p \le .01$, $^{***}p \le .001$. Percentages of males ranged from 0% to 100% in each examined outcome.

Table 3

Effect of gender on variability of autistic traits

AQ scale	Subgroup	Variance	*Q*	I^2	τ^2	*k*	Compared groups
Total score	Total sample	122.40	508.50	85.05	12096.64	77	Total *Q* within: 825010.71*
		96.41	419.87	83.57	10966.95	70	Total *Q* between: 1320.71*
	ASD sample	56.69	47.19	51.26	8719.17	24	Total *Q* within: 10499.97*
		30.99	20.33	31.14	5449.48	15	Total *Q* between: 21.67*
	Non-clinical sample	65.71	411.09	87.35	8102.77	53	Total *Q* within: 795778.13*
		65.42	375.49	85.62	8408.54	55	Total *Q* between: 1172.21*
Social behaviors/ social skills	Total sample	15.10	447.92	91.52	1150.02	39	Total *Q* within: 76112.36*
		8.85	214.37	86.01	914.12	31	Total *Q* between: 393.73*
	ASD sample	6.27	21.58	44.38	711.58	13	Total *Q* within: 3502.79*
		3.16	6.97	28.23	328.42	6	Total *Q* between: 85.39*
	Non-clinical sample	8.83	432.99	94.23	716.52	26	Total *Q* within: 68150.16*
		5.69	208.10	88.47	688.96	25	Total *Q* between: 386.12*
Commu-nication/ mindreading	Total sample	6.81	112.05	67.87	653.08	37	Total *Q* within: 57463.60*
		4.18	74.55	61.10	529.52	30	Total *Q* between: 98.18*
	ASD sample	4.94	22.46	51.02	421.77	12	Total *Q* within: 2210.16*
		2.47	7.04	43.15	175.74	5	Total *Q* between: 120.80*
	Non-clinical sample	1.87	52.67	54.43	422.10	25	Total *Q* within: 53205.58*
		1.71	50.70	52.66	422.10	25	Total *Q* between: 96.11*
Attention to details/ patterns	Total sample	8.79	188.70	79.86	517.64	39	Total *Q* within: 38464.99*
		5.04	134.64	77.72	411.45	31	Total *Q* between: 870.74*
	ASD sample	6.08	17.64	31.96	749.92	13	Total *Q* within: 3295.70*
		2.42	8.22	39.14	346.12	6	Total Q between: 145.93*
	Non-clinical sample	2.71	120.65	79.28	315.69	26	Total *Q* within: 34054.21*
		2.63	99.58	75.90	303.55	25	Total *Q* between: 812.08*
Attention switching/ tolerance of change	Total sample	6.73	138.09	73.93	611.22	37	Total *Q* within: 53558.39*
		3.59	91.31	68.24	495.58	30	Total *Q* between: 1695.56*
	ASD sample	5.08	29.42	59.22	480.08	13	Total *Q* within: 3830.98*
		1.80	10.54	52.55	221.57	6	Total *Q* between: 196.18*
	Non-clinical sample	1.65	59.00	61.02	360.20	24	Total *Q* within: 46098.87*
		1.79	56.03	58.95	360.20	24	Total *Q* between: 1588.97*
Imagination	Total sample	7.40	233.63	85.02	311.46	36	Total *Q* within: 31081.29*
		3.08	163.85	82.91	250.90	29	Total *Q* between: 1362.55*
	ASD sample	6.04	17.29	30.59	778.93	13	Total *Q* within: 3733.01*
		2.10	7.07	29.26	359.50	6	Total *Q* between: 0.80
	Non-clinical sample	1.36	101.23	78.27	164.19	23	Total *Q* within: 24933.00*
		0.98	90.65	75.73	164.19	23	Total *Q* between: 1425.03*

Note. AQ – Autism-Spectrum Quotient; ASD – autism spectrum disorder; *Q* – total variance, I^2 and τ^2 – between study variance, *k* – number of effect sizes. *$p \leq .001$. Upper values reflect the results for males and the lower values represent the results for females.

Table 4

Publication bias analyses of the examined outcomes

	Subgroup	Rosenthal's number of additional effect sizes to bring null relationship	Egger's intercept	Trim and fill analyses
Total score	Total sample	107 033 (5*555+10 = 2785)	48.75**	111 "missing" studies on the right side of the funnel plot From *M* = 31.91 to *M* = 39.30
	ASD sample	19 927 (5*106+10 = 540)	14.30**	21 "missing" studies on the right side of the funnel plot From *M* = 45.43 to *M* = 50.31
	Non-clinical sample	19 447 (5*449+10 = 2255)	51.19**	81 "missing" studies on the right side of the funnel plot From *M* = 29.49 to *M* = 35.52
Social behaviors/ social skills	Total sample	16 274 (5*203+10 = 1025)	17.55**	31 "missing" studies on the right side of the funnel plot From *M* = 9.72 to *M* = 11.31
	ASD sample	13 346 (5*36+10 = 190)	18.82**	2 "missing" studies on the right side of the funnel plot From *M* = 13.23 to *M* = 13.89
	Non-clinical sample	16 337 (5*167+10 = 845)	17.30**	26 "missing" studies on the right side of the funnel plot From *M* = 8.99 to *M* = 10.48
Communication/ mindreading	Total sample	11 722 (5*190+10 = 960)	13.32*	31 "missing" studies on the right side of the funnel plot From *M* = 6.75 to *M* = 7.78
	ASD sample	5486 (5*32+10 = 170)	13.02*	4 "missing" studies on the right side of the funnel plot From *M* = 10.09 to *M* = 10.91
	Non-clinical sample	10 523 (5*158+10 = 800)	12.86**	27 "missing" studies on the right side of the funnel plot From *M* = 6.09 to *M* = 7.03
Attention to details/ patterns	Total sample	14 804 (5*206+10 = 1040)	12.20**	34 "missing" studies on the right side of the funnel plot From *M* = 8.74 to *M* = 9.81
	ASD sample	15 721 (5*36+10 = 190)	14.91**	7 "missing" studies on the right side of the funnel plot From *M* = 9.62 to *M* = 10.97
	Non-clinical sample	15 035 (5*170+10 = 860)	13.08**	28 "missing" studies on the right side of the funnel plot From *M* = 8.56 to *M* = 9.60
Attention switching/ tolerance of change	Total sample	12 364 (5*196+10 = 990)	11.03**	43 "missing" studies on the right side of the funnel plot From *M* = 8.01 to *M* = 9.34
	ASD sample	11 035 (5*36+10 = 190)	19.72**	7 "missing" studies on the right side of the funnel plot From *M* = 10.91 to *M* = 12.22
	Non-clinical sample	16 803 (5*160+10 = 810)	11.02**	37 "missing" studies on the right side of the funnel plot From *M* = 7.39 to *M* = 8.62

(Table 4 continues)

Table 4

Table 4 continued

	Subgroup	Rosenthal's number of additional effect sizes to bring null relationship	Egger's intercept	Trim and fill analyses
Imagination	Total sample	11 725 (5*187+10 = 945)	10.29**	24 "missing" studies on the right side of the funnel plot From *M* = 6.92 to *M* = 7.69
	ASD sample	10 970 (5*35+10 = 185)	15.39**	22 "missing" studies on the right side of the funnel plot From *M* = 6.28 to *M* = 7.04
	Non-clinical sample	17 178 (5*152+10 = 770)	10.47*	

Note. ASD – autism spectrum disorder; *$p \leq .001$, **$p \leq .01$.

tic group. Moreover, a significant effect of sex/gender on the variability of autistic traits was observed. Males exhibited higher variability than females in the total score of autistic traits, as well as in the social behaviors/social skills, communication/mindreading, attention to details/patterns, attention switching/tolerance of change, and imagination subscales. Notably, this effect was more pronounced in the autistic group compared to the typically developing sample. Overall, these findings suggest that male sex has a greater impact than female sex, not only on the level but also on the variability of autistic traits. These results align with previous meta-analyses, which reported higher levels of autistic traits and symptoms of repetitive and stereotyped behaviors in males compared to females (Loomes et al., 2017; Van Wijngaarden-Cremers et al., 2014). The present study also supports the observation that sex/gender differences in the total level of autistic traits are found in non-clinical populations but not in clinical groups (Ruzich et al., 2015). Furthermore, these findings are consistent with the "greater male variability hypothesis" (Ellis, 1934/1984) in the context of autistic traits, which suggests that many biological dimensions exhibit distributions where males are overrepresented on the extremes compared to females (Wierenga et al., 2018, 2022). These results may stem from biological differences. For example, it has been found that prenatal sex steroid hormones such as testosterone are associated with a higher level of autistic traits (Auyeung et al., 2009, 2010). Additionally, Greenberg et al. (2018) in a large sample found that brains of autistic people, regardless of their sex, were on average more "masculinized".

These findings imply that similar effects may be observed in both clinical and non-clinical samples, supporting the notion that differences between autistic individuals and non-clinical groups are likely quantitative in nature (Baron-Cohen et al., 2001; Constantino & Todd, 2003; Ingersoll & Wainer, 2014). However, the strength and characteristics of effect sizes differ slightly between clinical and non-clinical samples, which lends validity to the concept of autism as a distinct state qualitatively different from the construct of autistic-like traits (Frazier et al., 2010, 2012, 2014). Further studies are needed to gain a better understanding of the role of sex/gender in the level and variability of autistic features in both autistic and non-autistic populations. For instance, previous meta-analyses have found that males with autism exhibit more symptoms of repetitive and stereotyped behaviors compared to females with this diagnosis (Van Wijngaarden-Cremers et al., 2014). However, no sex/gender effects were observed on social behavior or communication symptoms. These findings align with other studies suggesting that sex/gender differences may be associated with different expressions of autistic traits in females/women that do not align with established diagnostic criteria and tools (Begiatto et al., 2017; Bourson & Prevost, 2022; Rivet & Matson, 2011; Torske et al., 2023). Future studies should consider the influence of camouflaging in autism diagnosis. There is substantial empirical evidence indicating that adults with higher self-reported autistic traits engage more in camouflaging, particularly among females compared to males (Bargiela et al., 2016; Cook et al., 2021; Hull et al., 2020; Wood-Downie et al., 2021).

IMPLICATIONS AND GENERALIZABILITY

The present study holds significant theoretical and practical importance as it expands our understanding of the influence of sex/gender on the level and variability of autistic traits in clinical and non-clinical populations. The findings suggest that males may exhibit higher scores of autistic features compared to females, particularly in non-clinical groups versus autistic groups. Additionally, the variability of autistic traits may be greater in males compared to fe-

males, especially within the autistic group compared to the non-clinical sample. These findings have several important implications. Future research should focus on identifying the factors that can modify the effect of sex/gender on the level and variability of autistic traits, considering both clinical and non-clinical groups, as well as each specific group individually. Such studies would contribute to advancing our knowledge of the distinctions between autism and autistic-like traits concepts. These results represent a significant step forward, suggesting that the greater male variability, combined with the limited discriminative validity of diagnostic instruments in females, may lead to lower rates of ASD diagnosis in female cohorts. This discrepancy may arise due to inherent properties of the instrument scales, which inaccurately reflect continuous variations in actual psychological characteristics. Although this issue can affect both sex/gender groups, the group with greater variability is more resilient to this measurement error. The existence of distinct variability in female and male populations strongly supports the proposal to establish separate diagnostic cut-off points for each sex/gender group (Goldman, 2013). Hence, researchers and clinicians should consider that the profile of autism characteristics may significantly differ between males and females, particularly in the context of autism diagnosis.

LIMITATIONS AND FUTURE DIRECTIONS

This meta-analysis has a few limitations. Firstly, only two search engines were used during the final search process. Consequently, searching sources were biased by focusing only on electronic databases without including data from other resources (e.g. conferences, ongoing trials). Secondly, a number of studies had to be excluded due to inclusion and exclusion criteria (i.e., using the Autism-Spectrum Quotient, reporting mean (*M*) and standard deviation (*SD*) statistics, including either autism or neurotypical samples). Thirdly, there was no way to control study risk of bias assessment and certainty assessment for each examined outcome. Fourthly, the selection and coding of results were carried out by a single individual, who received comprehensive training and regular supervision from an expert experienced in meta-analyses. The accuracy of 25% of the coded data was checked by an expert in meta-analysis. Consequently, the potential bias associated with data coding in this study should be considered minimal. However, no inter-rater agreement/checking was conducted during the article screening process, and inter-rater checking was not performed prior to the data extraction process. Fifth, some information recommended by the PRISMA guidance for reporting systematic reviews (Page et al., 2021) was missed. Specifically, the number of duplicates was not controlled, and the exact number of exclusions based on specific reasons was not documented. Sixth, both the long and short versions of the AQ inventory were used, while scales created through factor analysis were excluded. Thus, the scales included in this study reflect a high level of theoretical similarity in defining autistic traits, despite differences in the AQ's psychometric characteristics. Meta-analysis is a set of techniques that combine the results of multiple scientific studies to generate a single and precise estimate of an effect. The idea behind meta-analysis is to analyze studies with different participant groups and questionnaires, treating dependent effect sizes as independent to avoid inflation. As a result, studies with more effect sizes carry more weight in the meta-analysis. The errors associated with meta-analysis in this study should be considered relatively low (Hunter & Schmidt, 2004; Scammacca et al., 2014). However, error correction was not applied, which may have impacted the findings by potentially introducing a downward bias in estimates of the level of autistic traits and artificial variation in effect sizes across studies (Hunter & Schmidt, 2004). Additionally, this study did not account for the dependency among multiple effect sizes, potentially leading to artificially reduced estimates of effect sizes and an increased type I error (Borenstein et al., 2009). Seventh, due to program limitations, only one data point for each group within the study was possible to code for each outcome. Therefore, a convergent data selection process was employed based on the level of effect size and the number of participants in this meta-analysis (López-López et al., 2018). Consequently, the results may be slightly underestimated. Eighth, future studies should include subscales from other questionnaires as well as broader factors to gain a better understanding of gender differences in the level and variability of autistic traits from a broader theoretical and psychometric perspective. Finally, it should be noted that there are various other factors that may modify the effect of sex/gender on the level and variability of autistic traits, such as transgender and gender-diverse experiences, age, culture, and IQ. However, these factors were not controlled for in this study due to the limitations of the statistical program.

Endnote

1 It is important to mention that sex refers to the biological processes that generally distinguish females from males. In contrast, gender refers to the social traits societies generally ascribe to women or men. Since the issue of the way of depicting sex/gender differences falls outside the scope of our paper, from now on, we will be using the terms sex/gender, males/men and females/women.

Disclosure

The authors declare no conflict of interest.

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