Determinants of Autism Spectrum Disorder: Supplementary Material

Supplementary Table S1. Non-Vaccine-Related Risk Factors Associated with Autism and Other Neurodevelopmental Disorders

Study (Author, Year)	Sample Size	Population Studied	Study design	Control group	Autism Verification Method	Key Findings	Neurodevelopmental Disorder rates
Brand et al., 2021	Population-based cohort	Nordic registry data	Cohort; sibling comparisons/ adjusted models	Pregnancies without HDP	Registry ASD diagnoses	HDP (chronic/gestational hypertension and preeclampsia) associated with modestly increased ASD risk in offspring.	NR
Yin et al., 2024	4.6M births (Sweden+Finland combined)	Population registers (Nordic)	Cohort with parental psychiatric history stratified	No parental psychiatric history	Registry diagnoses (ICD)	Parental psychiatric disorders (both parents, especially maternal) associated with higher ASD risk in offspring.	NR
Kinney et al., 2008	Ecological, statewide time-series	US regions exposed to hurricanes/tropical storms in gestation	Ecological natural experiment	Birth cohorts not exposed in utero (temporal/spatial comparisons)	State education/health records (autistic disorder)	Higher autism prevalence observed following severe prenatal storm exposure.	NR
Avalos et al., 2024	Large integrated-care cohort (early-pregnancy cannabis screen)	Kaiser Permanente Northern California births	Cohort (prospective exposure ascertainment via universal screening)	Women with negative cannabis screen	EMR/registry ASD diagnoses	Maternal cannabis use in early pregnancy not associated with child ASD; authors note need to study patterns later in pregnancy.	ASD diagnosed in 3.6% overall.
Zerbo et al., 2015	5,565 ASD cases; matched controls	Kaiser Permanente Northern California births	Case–control (registry-based)	Matched non-ASD controls	Clinical diagnoses in KPNC records	Maternal bacterial infections in 2nd–3rd trimesters associated with moderately increased ASD risk.	NR
Gong et al., 2019	Population and family-based case–control	Swedish registers; parental asthma and medication	Case–control with sibling/family analyses	Matched population controls; family comparisons	Registry ASD diagnoses	Parental (esp. maternal) asthma associated with slightly elevated offspring ASD risk; asthma medications during pregnancy not associated.	NR
Pagalan et al., 2019	132,256 births	Metro Vancouver, Canada	Population-based cohort	Lower exposure reference	Administrative /registry ASD diagnoses	Prenatal exposure to traffic-related nitrogen oxides (NO/NO_2 proxies) associated with increased ASD risk.	1.0% diagnosed with ASD by age 5 (1,307/132,256 births)
Raz et al., 2015	Case–control across US Nurse's Health Study II offspring	US births with modeled PM2.5 exposure	Case–control with spatiotemporal exposure modeling	Matched controls without ASD	Maternal report validated against records/clinical confirmation	Higher maternal PM2.5 exposure during pregnancy—particularly the	OR 1.57 (1.22–2.03) among non-movers; in a 3-period

						third trimester—associated with greater odds of ASD in children.	mutual model pregnancy PM_2.5 OR 1.63 (1.08–2.47). 3rd trimester per IQR: OR 1.42 (1.09–1.86)
Volk et al., 2013	279 ASD cases; 245 controls	CHARGE study (California)	Population-based case–control with modeled exposure (traffic, PM2.5/PM10, NO2)	Typically developing children matched from same catchment	Clinically confirmed ASD diagnoses	Higher prenatal and first-year exposure to traffic-related air pollution and PM2.5/PM10 associated with ~2× higher odds of ASD; NO2 also associated.	NR
Yin et al., 2023	Nationwide Swedish cohort; N>1M births	Sweden registers (maternal RA)	Population-based cohort with covariate adjustment	Unexposed births	Registry diagnoses (ICD)	Maternal rheumatoid arthritis associated with increased ASD risk in offspring.	NR
Brown et al., 2014	967 case–control pairs (1,132 autism cases in sampling frame)	Finnish Prenatal Study of Autism (national birth cohort with archived maternal sera)	Nested case–control	1:1 matched controls on sex, date/place of birth and residence	Registry ICD-10 F84.0 diagnoses; 96% ADI-R validation in a subsample	Maternal thyroid peroxidase antibody (TPO-Ab) positivity during pregnancy associated with ~80% higher odds of childhood autism vs. TPO-Ab negative mothers.	NR
Ge GM, Cheung ECL, Man KKC, et al., 2022	422,156 mother–child pairs; L-T4 exposed n=2,125	Population-based cohort (Taiwan)	Cohort with propensity weighting	Euthyroid mothers; pre-pregnancy L-T4 users	Administrative ASD diagnoses	Gestational levothyroxine use not associated with offspring ASD; increased preterm birth risk likely related to thyroid disease severity.	NR
Gardener et al., 2009	Meta-analysis (case–control and cohort studies; 9 on parity)	Multiple populations across included studies	Systematic review an meta-analysis	Varied by included study; population controls	Registry/clinical diagnoses (per included studies)	Across studies, associations between birth order/parity and autism were inconsistent; some reported higher risk in firstborn and high-parity births, overall non-monotonic patterns.	NR
Su et al., 2020	Meta-analysis (GWG and ASD)	Multiple countries	Systematic review and meta-analysis	Within IOM-recommended GWG	Varies	Gestational weight gain outside recommended ranges associated with higher ASD risk; excessive GWG stronger than insufficient.	Inadequate GWG vs. adequate: OR 1.18 (1.09–1.28); Excessive GWG vs. adequate: OR 1.14 (1.06–1.22)

Djuwantono et al., 2020	Meta-analysis (studies comparing ICSI vs IVF)	Multiple cohorts	Systematic review and meta-analysis	IVF without ICSI (reference)	Registry/clinical diagnoses	ICSI associated with higher ASD risk vs conventional IVF (RR≈1.49; 95% CI ~1.05–2.11).	NR
Curran et al., 2015	Meta-analysis + sibling-control within large cohorts	Multiple countries	Systematic review/meta-analysis; sibling-comparison	Vaginal delivery; sibling controls	Registry diagnoses	Cesarean delivery associated with ~20% increased ASD risk in conventional analyses, but association attenuated in sibling comparisons—suggesting confounding.	aOR 1.02 (0.89–1.17)
Khaled et al., 2016	50 ASD; 30 controls (approximate)	Egyptian children	Case–control (biomarkers)	Typically developing controls	Clinical diagnosis	Urinary porphyrin patterns and mercury exposure correlated with ASD severity.	NR
Morgan et al., 2010	13 ASD postmortem brains; 9 controls	Postmortem human brain tissue	Case–control (histopathology)	Neurologically typical postmortem donors	Clinical diagnosis prior to death; brain bank records	Increased microglial activation and density in dorsolateral prefrontal cortex in ASD.	NR
Arora et al., 2017	Deciduous teeth from 32 ASD cases; 32 controls	U.S./Sweden clinic-based samples	Case–control with tooth-matrix biomarkers	Age-matched typically developing controls	Clinical diagnoses	Dynamic uptake patterns showed higher late-gestation/early postnatal lead and altered zinc/manganese rhythms in ASD vs controls.	NR
Nickel et al., 2023	Adults with ASD; matched controls (N≈120+)	Adults (Germany)	Case–control (mitochondrial markers)	Age/sex-matched controls	Clinical diagnosis	Altered peripheral markers of mitochondrial function in adults with ASD.	NR
Zhao et al., 2023	67 ASD; 55 controls	Children (hospital-based)	Case–control (trace elements)	Age-matched typically developing children	Clinical diagnosis	Altered whole blood/urine trace elements profiles associated with ASD and behaviors.	NR
Zürcher et al., 2021	15 ASD; 18 controls (approx.)	Young adults	Case–control (PET imaging, TSPO)	Typically developing controls	Clinical diagnosis	Lower regional TSPO expression suggesting altered glial signaling in ASD.	NR
Chen SW et al., 2016	Meta-analysis: 9 case–control + 1 cohort; 9,775 cases; 952,211 controls	Mixed (global)	Systematic review and meta-analysis	Unaffected controls (varied)	DSM/ICD or registry across included studies	Maternal autoimmune diseases associated with ~34% higher ASD odds (pooled OR≈1.34).	NR
Dickerson et al., 2015	Ecologic analysis of 2,489 census tracts (ADDM data)	5 US ADDM sites (2000–2008)	Ecologic, multilevel regression	Area-level comparison (far vs. near industrial sources)	ADDM surveillance (record review)	Higher ASD prevalence in census tracts closest to facilities releasing As/Pb/Hg (adjRR≈1.27).	Living within 10 mi of industrial releases of Hg/Pb/As: aRR 1.27 (1.00–1.61)

Vargas et al., 2005	11 ASD brains; 6 controls (postmortem)	Postmortem human brain tissue	Case–control (pathology and cytokines)	Neurologically typical postmortem donors	Clinical diagnosis; brain bank records	Neuroglial activation and neuroinflammation in multiple brain regions in ASD.	NR
James et al., 2004	20 ASD; 33 controls	US clinic-based sample	Case–control (biomarker study)	Age-matched typically developing children	Clinical diagnosis (DSM-IV); clinic records	Evidence of impaired methylation capacity and increased oxidative stress biomarkers in ASD.	NR
Ding et al., 2023	5054	Children	Case-control study	Typically developing controls	Clinical diagnosis	Higher blood Hg/As/Cd/Pb levels observed in ASD vs controls.	NR
Wu S. et al., 2017	Meta-analysis (multiple studies)	Mixed (global)	Systematic review and meta-analysis	Unaffected controls (varied by study)	Varies; DSM/ICD across included studies	Both advanced maternal and paternal age associated with increased ASD risk.	OR 1.46 (1.30–1.64) Maternal age ≥35 vs 25–29, OR 1.75 (1.49–2.06) Paternal age ≥45 vs 25–29
Nordahl et al., 2011	Boys with ASD (regression vs. no regression); N~60	Preschool boys with ASD	Cross-sectional neuroimaging	Typically developing controls	Standardized clinical assessment	Brain enlargement associated with regressive ASD subtype.	Regression rate within ASD sample: 61/114 ≈ 53.5%
Windham et al., 2006	284 ASD cases; 657 controls	San Francisco Bay Area births (USA)	Case–control	Random controls from birth certificates	California DDS records / clinician diagnosis	Residential exposure to certain hazardous air pollutants associated with higher ASD odds.	NR
Schmidt et al., 2011	288 autism, 141 ASD, 278 typically developing controls	CHARGE (California) case–control study	Population-based case–control; gene–environment analyses	Frequency-matched general population controls from state birth files	Standardized clinical assessment at UC Davis MIND Institute (e.g., ADOS/ADI-R)	Periconceptional prenatal vitamin use (3 months before through first month of pregnancy) associated with lower autism risk (adjusted OR≈0.62); stronger protective effects in strata with folate-pathway risk genotypes.	NR
Cheslack-Postava et al., 2013	National cohort	Finnish births (national registries)	Population-based cohort	General population without ASD	Registry diagnoses (autism subtypes)	Risk for ASD varied by maternal parity and diagnostic subtype; patterns suggested non-linear associations across parity levels.	NR
Sandin et al., 2016	5,766,794 births; 30,902 ASD cases	Population-based cohorts from Sweden, Denmark, Israel, Norway, Western Australia	Population-based cohort with within-family (sibling) analyses	General population peers; sibling comparisons to control family-level confounding	Register-based ASD diagnoses from national health/education registries	Risk increased with both advancing maternal and paternal age; non-linear 'U-shaped' pattern with elevated risk also	ASD in full cohort: 28,290 / 2,697,315 ≈ 1.05%

						at very young maternal age; effects persisted in within-family models.	
Román et al., 2013	5,100 mothers with thyroid labs; outcomes in 4,039 children (81 probable autism by traits)	Generation R birth cohort, Netherlands	Prospective cohort	Children of mothers without severe hypothyroxinemia	Autistic traits by CBCL-PDP and SRS; 'probable autism' defined by high PDP+SRS	Severe early-gestation maternal hypothyroxinemia (fT4 <5th percentile with normal TSH) linked to ~4-fold higher odds of 'probable autism' based on traits at age 6.	NR
Vinkhuyzen et al., 2018	Thousands with 25(OH)D assays (Generation R)	Population-based cohort, Netherlands	Prospective cohort	Children of mothers with sufficient vitamin D	Autism-related traits (SRS) in mid-childhood (not clinical ASD diagnosis)	Gestational vitamin D deficiency associated with more autistic traits in offspring; associations robust to ancestry and seasonality adjustments.	NR
von Ehrenstein et al., 2019	≈2,961 ASD cases; ≈35,370 controls (10:1 ratio)	California Central Valley (statewide registries + pesticide application data)	Population-based case–control with GIS-based exposure within 2000 m of residence	Controls from same agricultural regions without exposure	Registry-confirmed ASD; ASD with comorbid ID analyzed separately	Prenatal exposure to several pesticides (e.g., glyphosate, chlorpyrifos, diazinon, malathion, avermectin, permethrin) associated with 10–20% higher ASD odds; stronger for ASD with intellectual disability.	Chlorpyrifos aOR 1.47 (1.23–1.75); Diazinon aOR 1.14 (0.96–1.35); Oxydemeton-methyl aOR 1.13 (0.98–1.31); Pyridaben aOR 1.27 (1.07–1.51)
Hornig et al., 2018	≈95,000 pregnancies (analytic N varies)	Norwegian Mother and Child Cohort / Autism Birth Cohort	Prospective cohort with trimester-specific fever reports	Mothers without reported fever; adjusted for confounders and fever in other trimesters	Registry/clinical ASD diagnoses	Second-trimester fever associated with increased ASD risk (aOR≈1.40); ≥3 fever episodes after 12 weeks linked to ~3× higher risk; antipyretic use attenuated some risks.	NR
Kosidou et al., 2016	>2.3 million births	Swedish national registers	Population-based cohort	Unexposed births; adjusted for parental factors	Register-based ASD diagnoses	Maternal polycystic ovary syndrome associated with increased ASD risk in offspring; risk higher when PCOS co-occurred with obesity.	OR 1.59 (1.34–1.88) Maternal PCOS vs none, OR 2.13 (1.46–3.10) Maternal PCOS with obesity vs neither
Wang et al., 2016	Meta-analysis (multiple studies)	Mixed (global)	Systematic review and dose-response meta-analysis	Normal BMI reference	Study-specific (clinical/registry)	Higher maternal BMI associated with increased ASD risk; ~16%	OR 1.36 (1.10–1.68) Maternal obesity vs normal BMI,

						increase per 5 kg/m².	OR 1.11 (1.00–1.23) Maternal overweight vs normal BMI
Christensen et al., 2013	655,615 births; 508 valproate-exposed	Denmark national cohort (1996–2006)	Population-based cohort	Children unexposed to valproate (other AEDs examined)	Registry ASD and childhood autism diagnoses	Prenatal valproate exposure associated with ~3× higher ASD risk (absolute risk 4.42%) and ~5× higher childhood autism risk.	ASD 4.42% after 14y in valproate-exposed vs 1.53% overall; childhood autism 2.50% in exposed. In epilepsy-only subset: ASD 4.15% exposed vs 2.44% unexposed; childhood autism 2.95% vs 1.02%.
Xiang et al., 2018	2,389,681 children (Swedish registers); N for T1D/T2D/GDM subsets	Sweden national cohort (1995–2012)	Population-based cohort with adjustments	Children of non-diabetic mothers; internal comparisons by diabetes type	National patient registers (ICD)	Maternal type 1 diabetes associated with the highest ASD risk; type 2 and GDM showed smaller elevations.	ADHD diagnosed in 5.2% of cohort during follow-up.
Rai D et al., 2013	4,429 ASD cases; 43,277 controls (drug data subset n≈18,524)	Stockholm Youth Cohort (Sweden)	Nested case–control; sibling and negative-control analyses	Age/sex-matched controls; sibling comparisons	Registry-based ASD diagnoses (with and without ID)	Maternal antidepressant use during pregnancy associated with increased ASD odds, particularly without ID; attenuation in sibling/psychiatric control analyses suggests confounding by indication.	NR
Walker, Cheryl and Krakowiak et al., 2014	CHARGE: 517 ASD; 194 DD; 350 TD controls (approx.)	California population-based case–control	Case–control	Typically developing (TD) and developmental delay (DD) controls	Standardized clinical assessment (e.g., ADI-R/ADOS)	Preeclampsia—particularly severe—associated with higher odds of ASD and DD; severity and placental insufficiency patterns showed dose–response.	NR
Maher et al., 2018	Meta-analysis of studies on hypertensive disorders of pregnancy (HDP)	Multiple countries	Systematic review and meta-analysis	Unexposed pregnancies (no HDP)	Varies by study (registry/clinical)	HDP exposure associated with increased risk of ASD and ADHD; highlights need for surveillance among HDP-exposed infants.	NR
Cheslack-Postava and Liu, 2011	California sibling births; N≈662,730 first- and	Population cohort (California)	Cohort with interpregnancy interval (IPI) exposure	Reference IPI (e.g., 36–47 months)	Registry/clinical diagnoses	Short IPI (<12 months) and very long IPI (>72 months) associated with	NR

	second-born pairs					higher ASD odds versus 36–47 months.	
Wiegersma et al., 2019	Cohort: 532,232 Swedish children; 299,768 mothers	Swedish national registers	Population cohort	Unaffected pregnancies; timing-specific comparisons	Registry-based diagnoses	Maternal anemia diagnosed ≤30 weeks associated with increased ASD, ADHD, and ID; late-pregnancy anemia not associated.	Children of mothers with anemia ≤30 wks: ASD 4.9%, ADHD 9.3%, ID 3.1%; anemia >30 wks: ASD 3.8%, ADHD 7.2%, ID 1.1%; no anemia: ASD 3.5%, ADHD 7.1%, ID 1.3%.
Crump et al., 2021	Swedish cohort: 4,061,795 singletons; follow-up to 2015	National registers (Sweden)	Population cohort with co-sibling analyses	Full-term (39–41 weeks) reference	Registry diagnoses (ICD-9/10)	Preterm and early-term birth associated with increased ASD risk; extremely preterm PR≈3.7–4.2; associations persisted in co-sibling models.	ASD prevalence by gestational age: extremely preterm 6.1%; very preterm 2.6%; moderate-to-late preterm 1.9%; early term 1.6%; full term 1.4%.
Schmidt et al., 2019	241 younger siblings of children with ASD	MARBLES high-risk sibling cohort (California)	Prospective cohort	Siblings whose mothers did not report prenatal vitamin use	Clinically assessed ASD outcomes at age 3 years	Maternal prenatal vitamin use in the first month of pregnancy associated with markedly lower ASD prevalence in high-risk siblings (14.1% vs 32.7%).	ASD recurrence in high-risk siblings: 14.1% with prenatal vitamins vs 32.7% without.
Guo et al., 2024	Meta-analysis across birth weight/GA categories	Multiple countries	Systematic review and meta-analysis	Normal birth weight / term reference groups	Varies	Low birth weight, very low birth weight, preterm, and small-for-gestational-age associated with increased ASD risk.	NR
Liu, L., Gao J., et al., 2017	Meta-analysis of ART vs. spontaneous conception	Multiple countries	Systematic review and meta-analysis	Spontaneous conception	Varies	Pooled estimates suggested a modestly elevated ASD risk with ART, but heterogeneity and residual confounding remain; later analyses show attenuation.	NR
Andreadou et al, 2021	Meta-analysis of ART and ASD	Multiple countries	Systematic review and meta-analysis	Non-ART	Varies	Statistically significant association overall between ART and ASD after adjustment.	NR

Jiang HY, Xu LL, Shao L, et al., 2016	Meta-analysis: 15 studies; >40,000 ASD cases	Mixed (global)	Systematic review & meta-analysis	Unaffected controls (varied by study)	Varies; DSM/ICD	Maternal infection during pregnancy associated with higher ASD risk (pooled OR>1).	NR
Xiang et al., 2015	Cohort: 322,323 children; 3,388 ASD diagnoses	Kaiser Permanente Southern California births (1995–2009)	Retrospective cohort	Internal comparison by exposure category	Clinical diagnosis within KPSC	Gestational diabetes diagnosed ≤26 weeks associated with increased ASD risk (adjusted HR≈1.42).	Unadjusted annual ASD incidence per 1,000: 1.7 (no diabetes), 2.0 (GDM 27–36 wks), 3.7 (GDM ≥37 wks), 4.4 (pre-existing diabetes).
Ames et al., 2023	10 ECHO cohorts (N>3,000 mother–child pairs)	U.S. multi-cohort (ECHO)	Prospective cohorts; mixture models for PFAS	Lower-exposed internal comparison groups	Autism-related traits (SRS) rather than diagnoses	Limited/inconsistent associations of prenatal PFAS with autism-related traits; overall relationship appears weak at population level.	NR
Li, Mengying and Fallin et al., 2016	Population-based cohort (Ontario, Canada)	Children in Ontario health databases	Retrospective cohort	Unexposed (no obesity/diabetes)	Health administrative records (ICD/clinical)	Maternal prepregnancy obesity + diabetes combined associated with increased risk of ASD and ID.	NR
Krakowiak et al., 2012	517 ASD; 172 DD; 315 general population controls	California CHARGE study	Case–control	General population and developmental delay groups	Standardized clinical assessment (ADI-R, ADOS)	Maternal metabolic conditions (diabetes, hypertension, obesity) associated with ASD and DD.	NR
Hernández-Díaz et al., 2024	4,199,796 unexposed children; epilepsy-restricted: 8,815 unexposed, 1,030 topiramate, 800 valproate, 4,205 lamotrigine (follow-up to age 8)	US claims cohorts (Medicaid and MarketScan), births 2000–2020	Population-based cohort; propensity score–adjusted	Unexposed to antiseizure medication; negative control (lamotrigine)	Claims/EMR diagnoses (registry/administrative)	After adjustment, ASD risk ↑ for valproate (aHR≈2.67); no significant ↑ for topiramate (aHR≈0.96) or lamotrigine (aHR≈1.00) vs. unexposed.	Cumulative ASD incidence by 8y (epilepsy-restricted): no ASM 4.2%; topiramate 6.2%; valproate 10.5%; lamotrigine 4.1%. In general unexposed population: 1.9%.
Bjørk et al., 2022	>4 million mother–child pairs across Nordic countries	Nordic national registers (Denmark, Finland, Iceland, Norway, Sweden)	Multinational cohort; adjusted and sensitivity analyses	Unexposed pregnancies; internal comparisons and dose analyses	National registries (ICD-coded diagnoses)	Valproate and topiramate exposure associated with increased risk of ASD and/or ID; lamotrigine not associated.	By 8y in children of mothers with epilepsy: ASD 1.5% unexposed vs 4.3% topiramate and 2.7% valproate; ID 0.8% unexposed vs 3.1% topiramate

							and 2.4% valproate.
Surén et al., 2013	MoBa cohort: 85,176 children; AD n≈270	Norwegian Mother and Child Cohort	Prospective cohort	Internal comparison by folic acid use	Registry/clinical diagnoses	Prenatal folic acid use around conception associated with lower risk of autistic disorder.	0.10% (64/61,042) with folic acid vs 0.21% (50/24,134) without.
Tsamantioti et al., 2022	Systematic review/meta-analysis (multiple cohorts and case–control)	Mixed (preterm and general populations)	Systematic review/meta-analysis	Study-specific unexposed groups	Study-specific (clinical/registry)	Chorioamnionitis exposure associated with increased risk of ASD and other NDDs; effects partly mediated by preterm birth.	NR
Kujabi et al., 2021	Meta-analysis emphasizing low-bias studies	Mixed (global)	Systematic review/meta-analysis	Non-jaundiced reference groups	Study-specific (clinical/registry)	Across low-risk-of-bias studies, no association between neonatal jaundice and ASD; earlier signals likely confounded.	NR
Jenabi et al., 2019	Meta-analysis of observational studies	Mixed (global)	Systematic review/meta-analysis	Non-jaundiced reference groups	Study-specific (clinical/registry)	Pooled estimates suggested neonatal jaundice associated with increased ASD risk.	Pooled OR 1.35 (1.02–1.68); Pooled RR 1.39 (1.05–1.74); Adjusted-only OR 1.19 (1.07–1.30)
Symeonides et al., 2024	Prospective cohorts (Australia/US) + mechanistic work; N≈1,700 children	General population cohorts	Prospective cohorts with maternal BPA + mechanistic studies	Lower BPA exposure groups	Clinical ASD diagnoses in subset; autism-related traits	Higher maternal BPA in late pregnancy associated with increased ASD risk in boys; mechanistic evidence implicates aromatase disruption.	NR
Shin et al., 2018	High-risk sibling cohort; N≈500–700	U.S. high-risk ASD families	Prospective cohort with maternal phthalate biomarkers	Lower-exposed internal comparison groups	Clinical ASD outcomes / traits	Mid-to-late pregnancy phthalate exposures not associated with ASD in this high-risk cohort.	NR
Ahlqvist et al., 2024	2.48 million Swedish births; sibling analysis	Sweden national registers (1995–2021)	Cohort with sibling-control analysis	Exposure-discordant siblings; population controls	Registry diagnoses	No association between acetaminophen use in pregnancy and ASD in sibling analyses; suggests confounding in conventional models.	10-yr absolute ASD risk: exposed 1.53% vs unexposed 1.33%.
Choi HM, et al., 2024	1,079,651 children's	Nationwide Danish cohort	Population-based cohort with	Unexposed pregnancies	National registry diagnoses	Antibiotic exposure during pregnancy or	(hazard ratio for autism spectrum

	records (Denmark)		advanced adjustment	and early infancy		early infancy not associated with ASD after adjustment.	disorder 1.06, 95% confidence interval 1.01 to 1.12; intellectual disorder 1.00, 0.93 to 1.07; language disorder 1.05, 1.02 to 1.09; and epilepsy 1.03, 0.98 to 1.08
Hamad et al., 2019	Large cohort using administrative data	Ontario/Canada health databases	Retrospective cohort	Unexposed pregnancies	Administrative /registry diagnoses	Prenatal antibiotic exposure associated with increased ASD risk; potential confounding acknowledged.	Incidence rates of ASD 1.62 vs 1.47 per 1,000 person-years (prenatally antibiotic-exposed vs unexposed)
Liew et al., 2023	73,731 children linked to residential water lithium estimates	Nationwide Denmark (1997–2013 births)	Nationwide cohort (exposure via water grid lithium)	Lower lithium exposure areas	National registries (ICD)	Higher prenatal exposure to lithium in drinking water associated with increased ASD risk; dose–response observed.	aOR 1.46 (1.09–1.96) Highest Li quartile in water vs lowest (ASD outcome)
Al-Haddad et al., 2019	1.79M Swedish births (1973–2014)	Sweden national registries	Population-based cohort	Unexposed pregnancies	Registry diagnoses	Maternal infection requiring hospitalization during pregnancy associated with increased ASD risk (and depression).	HR 1.79 (1.34–2.40)
Lizé et al., 2022	High-risk cohort and general-pop cohort (N~ hundreds to few thousands)	U.S. high-risk families; French cohort	Prospective cohorts with maternal OP biomarkers	Lower-exposed groups	Autism diagnoses/traits depending on study	Signals for increased autistic traits with higher chlorpyrifos/diazinon exposure; results vary across cohorts.	NR
Hertz-Picciotto et al., 2011	California clinic sample; N≈100	Children with and without ASD	Case–control (serum PBDEs)	Typically developing controls	Clinical ASD diagnoses	No association between circulating PBDE levels and ASD case status; does not exclude early-life effects.	NR
Choi JW. et al., 2024	ASD-enriched cohort (hundreds)	U.S. cohort	Prospective cohort with prenatal OPE biomarkers	Lower-exposed groups	Clinical ASD / non-typical development outcomes	Gestational OPE exposure not associated with ASD/non-typical development in this ASD-enriched cohort.	NR
Velez et al., 2023	1,370,152 live births (Ontario); ASD n≈22,409	Ontario, Canada population-based cohort (2006–2018)	Cohort; causal mediation analyses	Unassisted conception; subfertility without treatment; IVF vs ICSI	Administrative health/registry ASD diagnosis	Slightly higher ASD risk after infertility or fertility treatment vs unassisted conception (aHR≈1.16 for IVF/ICSI). Within	Incidence per 1000 person-years: unassisted 1.93; subfertility 2.49

						IVF group, ICSI vs IVF showed no significant difference (aHR≈1.05); mediation by multiple pregnancy (~78%) and preterm birth (~50%).	
Fountain et al., 2015	ICSI n=21,728; IVF n=13,753 (California)	California births linked to ASD registry	Population-based cohort	IVF without ICSI (reference)	State registry diagnosis of autistic disorder/ASD	Higher ASD risk in children conceived via ICSI vs IVF (singletons aHR≈1.65; multiples aHR≈1.71); associations stronger when ICSI without male-factor indication.	12.1 per 1,000 births in ART vs 5.5 per 1,000 in non-ART; analysis subset: 11.9 per 1,000 (ART) vs 7.0 per 1,000 (non-ART)
Wang et al., 2021	411,251 mother–child pairs (ASD analysis)	Hong Kong clinical data; antipsychotic prescriptions	Population cohort; sibling and past-exposure comparisons	No antipsychotic exposure; sibling-matched	Clinical/administrative ASD diagnoses	No increased risk of ASD after prenatal antipsychotic exposure; small crude associations attenuated in sibling/past-exposure analyses.	ASD dx during follow-up: 27/706 (3.82%) exposed vs 8,688/410,545 (2.12%) unexposed; cohort overall 8,715/411,251 (2.12%)
Murphy et al., 2024	Large cohort	Ontario, Canada (exposure in and before pregnancy)	Population-based cohort	Lower exposure reference	Administrative ASD diagnosis	NO_2 exposure before and during pregnancy associated with ASD; relationships for O_3 and $PM_{2.5}$ were mixed.	NR
Flanagan et al., 2023	Statewide birth registry linkage	New Jersey (source-specific PM components)	Case–control using source apportionment	Births without ASD (matched)	Registry ASD case identification	Certain local, source-specific PM sources during pregnancy are associated with higher odds of ASD; heterogeneity by source.	Adjusted OR (per IQR) 1.06 (1.01–1.12)
Robinson-Agramonte et al. (2022)	154 articles	ASD	Systematic review	Yes	Not stated	Summarizes evidence of immune dysregulation in ASD, including altered cytokine profiles and immune cell function; synthesis across studies without new primary data; does not establish causality.	NR
Khan FY, Kabiraj G, Ahmed	30 studies	Women aged 16+	Systematic Review	Not stated	Not stated	sufficient data from multiple populations and	NR

MA, et al., 2022						studies to say that acetaminophen is not as safe as it is considered.	
Xu Y, Yang X, Chen D, et al. 2022	107,752	ASD individuals	Meta-analysis	Not stated	Not stated	The findings revealed that maternal pesticide exposure was positively related to ASD and ADHD in children.	NR
Román P, Ruiz-González C, Rueda-Ruzafa L, Cardona D, Requena M, Alarcón R. 2024	52,393	Andalusia population	case-control study	Yes	Not stated	association between prenatal exposure to various compounds and the risk of developing ASD or lower performance on neurodevelopmental tests.	NR
Pu Y, Ma L, Shan J, Wan X, Hammock BD, Hashimoto K., 2021	Not stated	Pregnant ddY mice	Experiment research	Yes	Not stated	The exposure of glyphosate during pregnancy and lactation may cause ASD-like behavioral abnormalities in male juvenile offspring.	NR
Bolton JL, Marinero S, Hassanzadeh T, Natesan D, Le D, Belliveau C, et al, 2017	Not stated	TLR4-deficient Mice	Animal experiment	Yes	Not stated	first to directly test and confirm the critical role of TLR4, in the effects of prenatal air pollution exposure on microglial activation and/or development in the offspring	NR
Philippat C, et al., 2018	203	mother-child pairs of the ongoing MARBLES (mother-child cohort)	Systematic review	Not stated	clinically confirmed diagnoses	dimethylthiophosphate (DMTP) pregnancy concentration tended to be associated with an increased ASD risk among girls (OR for a doubling in the DMTP concentration: 1.64 (95%CI, 0.95; 2.82))	OR (per doubling DMTP) 1 .64 (0.95–2.82) *girls only ASD at 36 mo.*
Eshraghi RS, Deth RC, Mittal R, et al., 2018	Multiple studies	ASD patients	Autism/ASD-related outcome	Not stated	Clinical/registry diagnosis	The microbiome of the human gut can be seen to play an important role in the etiology of autism	NR
Apte, et al., 2023	Multiple studies	ASD	Autism/ASD-related outcome	Yes	Not stated	Wnt2 is also hypothesized as a potential contributor to ASD etiology	NR

Razi, et la., 2020	Multiple studies	ASD	Autism/ASD-related outcome	Yes	Not stated	studies suggest that *MTHFR* poly morphisms may be associated with the risk of ASD	NR
Dehesh, et al., 2024	41 articles	ASD	Autism/ASD-related outcome	Yes	Not stated	greater paternal and maternal ages were associated with an increased risk of autism in their children	Maternal 1.47 (1.33–1.62); Paternal 1.51 (1.40–1.62)
Laverty, et al., 2021	Multiple studies	ASD	Autism/ASD-related outcome	Not stated	Not stated	odds of an autism diagnosis were 3.3 times higher in individuals born preterm than in the general population	Pooled ASD prevalence among preterm varied ~6–20%, odds of autism diagnosis 3.3× higher vs general population (95% CI 0.24–47.60)
Matelski, Van de Water, 2016	Multiple studies	ASD	Autism/ASD-related outcome	Not stated	Not stated	mixed and multifactorial etiology for ASD,.	NR
Gillberg, et al., 2017	Population based study	ASD	Autism/ASD-related outcome	Not stated	validated DSM-IV-based interview	rate of ESSENCE in febrile seizures and epilepsy was significantly higher than in the total population without seizures	NR
Duffy et al., 2017	Case-control study	ASD	Autism/ASD-related outcome	Yes	medical record	incidence rate ratio of febrile seizure after vaccination was 23 (95% confidence interval 5.13 to 100.8), and the attributable risk was 3.92 (95% confidence interval 1.68 to 6.17) febrile seizure cases per 100,000 persons vaccinated	NR
Nilsson et al., 2022	community-based cohort	ASD	Autism/ASD-related outcome	yes	Parental survey	There was a trend for Neurodevelopmental symptom scores to be higher in the FS group	either 4-5 or age 9-10 was 41% (30/73)
Breece E, Paciotti B, Nordahl CW, Ozonoff	Case-control	ASD	Autism/ASD-related outcome	yes	Clinical/registry diagnosis	Myeloid dendritic cell frequencies are increased in children with autism spectrum	NR

S, Van de Water JA, Rogers SJ, Amaral D, Ashwood P, 2013						disorder and associated with amygdala volume and repetitive behaviors	
Griffiths KK, Levy RJ, 2017	Mechanistic / animal / in vitro	Narrative review	ASD	Autism/ASD-related outcome	Clinical/registry diagnosis	substantial associative evidence that mitochondrial dysfunction and oxidative/redox abnormalities occur in a subset of individuals with ASD	NR
Gardner RM, Brynge M, Sjöqvist H, Dalman C, Karlsson H., 2024	not stated	Narrative review of studies on maternal infections/autoimmunity/high BMI (maternal immune activation) and later ASD in offspring	Narrative Review	not stated	not stated	Reviews evidence on maternal inflammatory exposures and ASD; emphasizes substantial risk of familial/genetic confounding and evaluates causal inference attempts; does not provide a single causal estimate.	NR
Bose, C., Valentine, G.C., Philips, K. et al, 2023	n=306 toddlers at age 2 (mother–child pairs)	Pregnant people with periodontal disease from the MOTOR RCT; offspring assessed at 2 years (USA)	Follow-up of randomized trial (periodontal treatment during pregnancy vs. after pregnancy)	Deferred/postpartum periodontal treatment	M-CHAT screen at ~2 years (screening positivity, not clinical diagnosis)	Treating periodontal disease during pregnancy reduced risk of a positive ASD screen (adjusted RR 0.53, 95% CI 0.29–0.99); positive M-CHAT associated with higher IL-6 in cord blood and maternal change in IL-6.	0.53 (0.29–0.99)
Starzyńska A, Wychowański P, Nowak M, Sobocki BK, Jereczek-Fossa BA, Słupecka-Ziemilska M., 2022	not stated	Narrative review on maternal periodontitis and systemic diseases in offspring (broad outcomes)	Narrative Review	not stated	not stated	Suggests maternal periodontitis may impact pregnancy outcomes and potentially offspring epigenome/health; not ASD-specific and no extractable ASD metrics.	NR
Neeman, Shahar & Hemo, Maor & Meiri, Gal & Shmueli, Dorit & Menashe, Idan. 2025	153,321 children (2016–2020 births; Israel)	Singleton live births among members of Clalit Health Services; follow-up through May 2024	Retrospective cohort using electronic medical records	Offspring of mothers not vaccinated against influenza during pregnancy	ASD diagnosis from CHS electronic medical records	Crude HR suggested higher ASD risk (HR 1.22), but after adjustment no association (aHR 0.97, 95% CI 0.91–1.05). Conclusion: maternal influenza vaccination	NR

						during pregnancy not associated with increased ASD risk.	
Marchand GJ, Massoud AT, Abdelsattar AT, McCullough PA. 2024	Meta-analysis of 3 RCTs; maternal participants ≈ 7,318 vaccinated vs 5,525 placebo	Pregnant individuals receiving RSVpreF vaccine (late 2nd/3rd trimester), trials of Pfizer and GSK products	Meta-analysis of randomized, placebo-controlled trials	Placebo	not stated	Reduced infant RSV-LRTI, severe illness, and RSV-related hospitalizations in vaccine arm; higher preterm delivery risk (RR 1.24, 95% CI 1.08–1.44); no difference in neonatal deaths.	NR

Supplementary Table S2. Studies Reporting No Association Between Vaccination and Neurodevelopmental Disorders (Neutral Findings)

Study (Author, Year)	Sample Size	Population Studied	Study Design	Controlled Confounders	Autism Verification Method	Vaccination Verification Method	Key Findings	Rates of NDD, Measures of Association
Taylor, Swerdfeger & Eslick, 2014	Meta-analysis: 10 studies; ≈1.26 million children + 9,920 case-control participants	Cohorts and case-controls across multiple countries	Systematic review and meta-analysis	Study-level adjustments as reported; pooled analysis	Study-reported clinical/registry diagnoses	Study-reported records/registries (MMR, thimerosal, mercury exposure)	No association between any vaccine exposure (MMR, thimerosal, Hg) and autism/ASD	MMR: 0.90 (0.68–1.19); Thimerosal-exposure: 0.85 (0.60–1.20)
Andrews et al., 2004	≈110,000 children	UK general practice cohorts	Retrospective cohort	Sex, birth weight, gestational age, maternal age, parity, socioeconomic factors	Primary care diagnostic records	Practice immunization records with thimerosal content	No causal association between thimerosal and neurodevelopmental disorders, including ASD	By 3 mo: 0.89 (0.65–1.21); by 4 mo: 0.94 (0.73–1.21); HgAll per unit: 0.99 (0.88–1.12)
Jain et al., 2015	≈95,000 children with older siblings	US privately insured children with and without older siblings with ASD	Retrospective cohort	Age, birth year, sex, older sibling ASD status, health care utilization and plan enrollment factors	Claims-based ASD diagnoses (validated within system)	Administrative claims / vaccination records	No link between MMR and ASD, including among children with an older autistic sibling (higher genetic risk)	Overall ASD: 994 / 95,727
Madsen et al., 2002	537,303 children	Nationwide Danish birth cohorts (1991–1998)	Retrospective cohort (registry linkage)	Age, sex, birth cohort/calendar period, registry-based perinatal and sociodemographic factors	Danish Psychiatric Central Register diagnoses	Danish National Board of Health immunization registry	No association between MMR and autistic disorder or other ASD; risk not related to age at vaccination or time since vaccination	autistic disorder 316; other ASD 422. Among 8-year-olds: prevalence per 10,000 = 7.7 (autistic disorder) and 22.2 (other ASD)
Hviid et al., 2019	657,461 children; 6,517 ASD cases	Nationwide Danish birth cohorts (1999–2010)	Retrospective cohort (registry linkage) with Cox models	Age, birth year, sex, other childhood vaccines, sibling ASD, composite risk score of autism risk factors	Danish national registries (hospital/outpatient diagnoses)	Danish vaccination registries	MMR not associated with increased autism risk overall or in risk-defined subgroups; no clustering after vaccination	ASD cases 6,517 over 5,025,754 person-years
Smeeth et al., 2004	1,294 ASD cases; 4,469 controls	UK General Practice Research Database	Matched case–control with additional time-trend analyses	Practice, age matching; adjusted for consultation rates and recorded risk factors	GPRD clinical diagnoses	General practice immunization records (GPRD)	No association of MMR with ASD; no temporal clustering around vaccination	Adjusted OR for pervasive developmental disorder vs MMR 0.86 (0.68–1.09)

Mrozek-Budzyn et al., 2010	96 ASD cases; 192 controls (matched)	Polish children (Krakow region)	Matched case–control	Maternal education, socioeconomic, perinatal factors, child's health history	Specialist clinical evaluation/records	Medical records/parent-held immunization cards	No association between MMR and autism	Vaccinated before diagnosis (any vaccine vs none): OR 0.28 (0.10–0.76). MMR vs unvaccinated: OR 0.17 (0.06–0.52). MMR vs single measles: OR 0.44 (0.22–0.91)
Honda et al., 2005	Population-level incidence across birth cohorts (1988–1996)	Yokohama, Japan (MMR withdrawn in 1993)	Ecological time-trend (total population)	Secular trends considered; no individual-level confounders	Community diagnostic centers / educational services records	Policy change (withdrawal) serves as exposure contrast	Autism incidence continued to rise after MMR withdrawal—argues against a causal link	Seven-year cumulative ASD incidence overall: 88.5 per 10,000 (95% CI 78.1–98.8). Birth cohorts 1988–1992 (MMR in use): 47.6–85.9 per 10,000. Cohorts 1993–1996 (MMR withdrawn): 96.7–161.3 per 10,000.
Hviid et al., 2003	Nationwide birth cohorts (Denmark, 1990–1996)	Danish children exposed vs unexposed to thimerosal-containing vaccines	Retrospective cohort	Birth cohort/calendar time, age, sex, other registry covariates	Danish psychiatric/birth registries	Vaccination registries with thimerosal content classification	No association between thimerosal exposure and autism	RR 0.85 (0.60–1.20). Other ASD: RR 1.12 (0.88–1.43). Dose–response (per 25 μg ethylmercury): RR 0.98 (0.90–1.06) for autism.
Verstraeten et al., 2003	HMO databases, Phase I and II (tens of thousands of children)	US Vaccine Safety Datalink health plans	Two-phase retrospective cohort	Demographics, birth characteristics, health service use	Medical records / diagnostic codes	Electronic immunization records with ethylmercury dose estimation	No consistent increased risk of ASD with thimerosal exposure	cumulative exposure at 3 months resulted in a significant positive association with tics (relative risk [RR]: 1.89; 95% confidence interval [CI]: 1.05-3.38).
Madsen et al., 2003	Ecologic: 956 autism cases (1971–2000)	Danish children aged 2–10; pre vs post thimerosal removal (1992)	Ecologic time-trend	None at individual level (ecological)	Danish Psychiatric Central Research Register	Policy change (removal of thimerosal) as exposure contrast	Autism incidence increased after thimerosal removal—argues against association	NR

Price et al., 2010	256 ASD cases; 752 controls	3 US managed-care organizations	Matched case–control	Maternal and perinatal factors, demographics, health care use; conditional logistic regression	Standardized in-person evaluations validating ASD diagnoses	Immunization registries + medical charts + parent interview	No association between prenatal/infant thimerosal exposure and ASD (including AD and regressive ASD)	aOR per 2-SD increase in EtHg: Prenatal 1.12 (0.83–1.51); Birth–1 mo 0.88 (0.62–1.26); Birth–7 mo 0.60 (0.36–0.99); Birth–20 mo 0.60 (0.32–0.97)
DeStefano et al., 2013	256 ASD cases; 752 controls	3 US managed-care organizations	Matched case–control	Perinatal/maternal factors, demographics, health care use	Standardized evaluations validating ASD diagnoses	Immunization registries & records (antigen totals summed by vaccine)	No association between total antigen exposure by 3, 7, or 24 months and ASD (incl. AD, regressive ASD)	aOR per 25-antigen increase: 0–3 mo 0.999 (0.994–1.003); 0–7 mo 0.999 (0.997–1.001); 0–24 mo 0.999 (0.998–1.001)
Ip, Patrick and Wong, Virginia et al., 2004	Thimerosal	82	Case-control study	Not stated	Not stated	Not stated	result contributed to the conclusion that there was "no causal relationship" between thimerosal in vaccines and autism.	Blood Hg (nmol/L): ASD 19.53 vs controls 17.68 (P=.15). Hair Hg (ppm): ASD 2.26 vs 2.07 (P=.79)
Andersson et al., 2025	≈1.2 million children; 50 pediatric outcomes evaluated	Nationwide Danish cohorts (1997–2018)	Retrospective cohort; aluminum exposure quantified from vaccine schedule	Age, sex, birth year, other vaccines/health factors (per pre-registered analysis)	National registries (hospital/outpatient)	Danish vaccination registries; cumulative aluminum exposure (mg) to age 2 y	No association between aluminum-adjuvanted vaccines and neurodevelopmental disorders, including ASD	HR per 1 mg Al exposure: *Any neurodevelopmental disorder* 0.93 (0.90–0.97); ASD 0.93 (0.89–0.97)
Zerbo et al., 2017	196,929 children	Kaiser Permanente Northern California births (2000–2010)	Retrospective cohort	Maternal age, race/ethnicity, parity, prenatal care, comorbidities, socioeconomic proxies	Repeated ASD diagnoses in EHR using ICD-9 codes	Maternal vaccination captured in EHR (timing by trimester)	No association of maternal influenza infection or vaccination during pregnancy with ASD in offspring; first-trimester signal not significant after multiple-testing correction	aHR for ASD: Any-time in pregnancy 1.00 (0.93–1.08). First trimester 1.20 (1.04–1.39) but not significant after multiple-comparisons correction
Fombonne E, Zakarian R, Bennett A, Meng	Population-based (all public-school	Montreal, Quebec (1997–98 to 2002–03)	Administrative prevalence + ecological	Logistic regression across age bands; sex examined;	School board special-needs teams using MEQ autism/PDD	Ecological: provincial schedules & coverage surveys;	PDD prevalence rose substantially across	PDD prevalence: 64.9 per 10,000 overall;

L, McLean-Heywood D (2006)	children aged 5–14 across 18 Montreal school boards; multiple birth cohorts)		linkage to immunization policy/coverage	no individual-level immunization data	educational codes aligned with DSM-IV PDD categories	cumulative thimerosal by schedule; no individual-level records	cohorts; increases were not associated with thimerosal exposure patterns or MMR coverage differences.	autistic disorder 21.6/10,000; PDD-NOS 32.8/10,000; Asperger 10.1/10,000. By thimerosal exposure: thimerosal-free cohorts 82.7/10,000 vs thimerosal-exposed 59.5/10,000
Miles JH, Takahashi TN (2007)	214 families with complete obstetric/Rh data	Families of children with autism evaluated at a university autism clinic (USA)	Observational analysis of clinic cohort (retrospective exposure ascertainment)	Subgroup/stratified analyses by phenotype, gender, IQ, regressive onset, head circumference, dysmorphology, and "essential" vs "complex" autism	Clinic-based ASD diagnosis (methods not detailed in abstract)	Maternal Rh status and Rh immune globulin exposure from interviews and medical records	No association between maternal Rh status or RhIG in pregnancy and autism; negative across all subgroups.	NR
Baird G, Pickles A, Simonoff E, et al. (2008)	ASD n=98; controls n=142 total (SEN n=52; TD n=90)	UK community sample, vaccinated children aged 10–12 years	Community case–control with serology	Not a confounder-driven model; groups compared by design	ADOS-G/ADI-R with clinical consensus to ICD-10	District records, parent records, and GP information verified MMR doses	No differences in measles antibody titres between ASD and controls; no dose–response with symptom severity or regression.	NR
Thompson WW, Price C, Goodson B, et al. 2007	1,047 children aged 7–10	Multi-site U.S. (Vaccine Safety Datalink)	Cohort exposure–outcome study with standardized neuropsych testing	Extensive potential confounders obtained from interviews and medical charts (demographic, prenatal/perinatal, child health, site)	Not an autism study (neuropsych outcomes only)	Immunization records + parent interviews	No consistent association between early thimerosal exposure and neuropsychological outcomes; a few small associations likely due to chance.	NR
Hornig M, Briese T, Buie T, et al. 2008	AUT+GI cases n=25; GI-only controls ≈n=13	Children 3–10 y with GI indications for colonoscopy (MGH/Columbia/CDC)	Triple-blinded case–control; multi-lab RT-PCR on bowel biopsies	Age-stratified recruitment; exclusion of recent MMR; standardized diagnostic review	DSM-IV-TR diagnosis confirmed; ADI-R; clinician review; excluded non-AUT PDDs/genetic syndromes	Pediatrician records confirmed dates/types/lot numbers of MMR; primary exposure assay was measles RNA detection in gut	No concordant detection of measles vaccine–strain RNA in ASD cases vs controls; timelines of MMR, GI onset, and ASD onset showed no causal pattern.	NR

Schechter R, Grether JK (2008)	Statewide administrative counts (California DDS)	California DDS clients, time-trend analysis pre/post thimerosal removal	Ecological time-trend using administrative data	Not applicable (ecological); age-specific trends examined	DDS autism eligibility/category (professional diagnoses recorded in DDS)	None (ecological comparison to timing of thimerosal removal; no individual vaccine records)	Autism caseload/rates continued to increase after removal of thimerosal from childhood vaccines; no evidence of a reversal.	Prevalence (per 1,000): among 3-year-olds rose 0.3 → 1.3 (1993→2003 birth yrs); peak at age 6 in 2006 was 4.5/1,000; among ages 3–5 by quarter 0.6 → 2.9/1,000 (1995→2003)
Tozzi AE, Bisiacchi P, Tarantino V, et al. (2009)	1,403 (≈70% of invitees from 1992–93 pertussis vaccine trial)	Italian cohort randomized in infancy to vaccines with different thimerosal	Follow-up of randomized exposure; neuropsych testing at ~10 years	Randomization; multivariate linear regression (gender and other factors as modeled)	Not an autism study (neuropsych outcomes only)	Trial assignment/records determined cumulative ethylmercury (62.5 vs 137.5 µg)	Only 2/24 outcomes differed (girls only); differences small and plausibly due to chance; no overall adverse neuropsych effect.	NR
Fombonne E, Chakrabarti S (2001)	Clinic series	Children with autism seen 1987–1999 at a UK clinic	Clinical series comparing features & timing vs MMR	Not a confounder-modeled analysis	Clinical diagnosis of autism (clinic-based)	Computerized immunization records provided MMR dates	No evidence for a "new variant" of MMR-induced autism with distinct features/timing; findings argued against an MMR-linked phenotype.	NR
Mäkelä A, Nuorti JP, Peltola H (2002)	535,544	Finnish national cohort linked to hospital and vaccination registers	Record-linkage cohort; observed vs expected analyses; clustering tests	Not confounder-modeled for autism; risk windows analyzed	Hospital discharge diagnoses for neurologic outcomes (ICD codes; includes autistic disorders)	Individual MMR vaccination data from national registry	No clustering of encephalitis, aseptic meningitis, or autistic disorder after MMR; 352 hospitalizations for autistic disorders observed overall in follow-up.	NR
Pichichero ME, et al. (2002)	61 infants (40 received TCVs; 21 received TCV-free)	Infants receiving routine vaccines in U.S. pediatric practices	Descriptive pharmacokinetic study (blood, urine, stool Hg)	Not applicable	Not an autism study	Vaccine administration per schedule; biologic sampling pre/post	Ethylmercury was rapidly eliminated; peak blood Hg levels low and declined quickly; no safety signals identified in	NR

							this PK context.	
Wilson K, Mills E, Ross C, McGowan J, Jadad A (2003)	12 controlled epidemiologic studies synthesized	Literature on MMR & ASD	Systematic review	Quality appraisal of included studies	As per included studies	As per included studies	No evidence of association between MMR and ASD; one analysis found a transient rise in parental concern in one window, others negative.	NR
Heron J, Golding J; ALSPAC (2004)	>14,000 in the ALSPAC birth cohort (1991–1992 births; UK)	UK population birth cohort with detailed vaccine timing	Prospective cohort (developmental & behavioral outcomes vs thimerosal dose by 3/4/6 mo)	Adjusted for birth weight, gestation, gender, maternal education, parity, housing tenure, maternal smoking, breastfeeding, ethnic origin	Not an autism study per se (broad developmental outcomes)	Child health records used to compute age-specific TCV exposures	No convincing evidence that early thimerosal exposure adversely affected neurologic/psych outcomes; many unadjusted "beneficial-appearing" results attenuated after adjustment.	NR
Holt N, et al., 2017	MMR1 (measles-mumps-rubella, first dose)	Cross-sectional study	Denmark, Central Denmark Region; 19 general practices; 1,712 children aged 18–42 months flagged as MMR1-negative in registers were reviewed (246 listed as "unvaccinated" in registers) against charts.	NR (coverage study)	NR	Medical-record review and reconciliation with billing/invoice codes and regional registers	MMR1 coverage was 94% by medical records vs 86% via register data; 55% (135/246) of children marked unvaccinated in the registry were actually vaccinated	NR
Taylor et al. (1999)	498 autism cases *(ICD-10 confirmed n=293: core=214; atypical=52; Asperger=27)*	UK North Thames registers & special schools; birth cohorts since 1979; linked to child-health systems	Record-linkage time-trend + self-controlled case-series (post-MMR clustering)	Trend windows / within-case comparison; no full individual-level confounder model beyond age/period	Clinical records; ICD-10 confirmation in subset	Child Health Computing System immunization database	No step-up in incidence after MMR introduction (1988); no age-at-diagnosis shift by vaccination status; no temporal clustering after MMR; regression not clustered (single 6-mo	Relative incidence: 1-yr 0.94 (0.60–1.47); 2-yr 1.09 (0.79–1.52); regression 0–2 mo 0.92 (0.38–2.21), 0–4 mo 1.00 (0.52–1.95)

							interval likely artifact)	

Supplementary Table S3. Studies Indicating a Positive Association Between Vaccination, Vaccine Components, and Neurodevelopmental Disorders

Study (Author, Year)	Exposure/Vaccine	Study Type	Population/Model	ASD Outcome	Autism Verification Method	Vaccination Verification Method	Key Findings	Rates of NDD, Measures of Association
Nevison C, 2025	Thimerosal-containing vaccines (historical removal/reintroduction timeline; indirect ecological exposure)	Retrospective ecological study	U.S. national data, Autism and Developmental Disabilities Monitoring (ADDM) Network, birth years 1992–2014	Autism/ASD-related outcome	ADDM registry (CDC surveillance network)	Based on historical vaccine formulation and public policy changes	Nationwide fraction of ASD cases with co-occurring ID fell from 48% (1992) to 31% (2002) after thimerosal removal from childhood vaccines, then rose to 40–41% (2014) following its reintroduction via influenza vaccination for infants and pregnant women. Pattern inconsistent with diagnostic expansion theory and suggests vaccine-derived mercury may modulate autism severity.	NR
Melissa Anderson-Chavarria, Jane Turner, 2023	Vaccination	Qualitative ethnographic study	35 parents of autistic children	Autism/ASD-related outcome	Parental Survey	Parental Survey	Ethnographic interviews revealed that most parents attributed autism to a genetic predisposition “triggered” by environmental factors. Vaccines were discussed in all interviews: 18 parents rejected any vaccine link, 3 attributed autism solely to vaccines, and 14 considered vaccines one of several possible triggers.	NR
Geier DA, Kern JK, Homme KG, Geier MR, 2017	Vaccination	Retrospective case–control study using Vaccine Safety Datalink (VSD)	Infants ≤15 months; evaluated for ASD, tic disorder (TD), and ADHD vs matched controls	Autism/ASD-related outcome	Clinical diagnoses recorded in VSD medical records	Vaccine exposure verified via VSD immunization registry	Increased cumulative ethylmercury exposure from thimerosal-containing Hib vaccines within the first 15 months of life was associated with higher odds of ASD, TD, and ADHD. On a per 25 µg Hg basis,	OR 1.49 (1.36–1.63) per 25 µg Hg for ASD; OR 1.43 (1.28–1.59) for TD; OR 1.50 (1.37–1.64) for

							odds ratios were 1.49 for ASD, 1.43 for TD, and 1.50 for ADHD (all $p < 0.001$). No association observed for non-neurodevelopmental control outcomes. Findings support a dose-dependent relationship between thimerosal and abnormal connectivity spectrum disorders.	ADHD ($p < 0.001$)
Vestergaard M, Hviid A, Madsen KM, et al, 2004	Vaccination	National Danish Cohorts (1991-1998)	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Danish population cohort (n≈537k): risk of febrile seizures was transiently higher in the 0–14 days after MMR (RR 2.75; 95% CI 2.55–2.97).	RR 2.75 (2.55–2.97) for FS within 14 days of MMR; absolute +1.56/1 000 at 15–17 mo; no ↑ epilepsy long-term
Geier MR, Geier DA, 2004	Vaccination	VAERS brief communication	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable (	VAERS brief communication (2003): reported higher autism reporting after thimerosal-containing DTaP vs thimerosal-free; male:female reporting ratio for autism ≈17:1; authors concluded increased reporting of NDs after TCVs	Autism OR 1.8 (p<.05); mental retardation OR 2.6 (p<.002); speech disorder OR 2.1 (p<.02); personality disorder OR 2.6 (p<.01); thinking abnormality OR 8.2 (p<.01)
Geier DA, Geier MR, 2003	Vaccination	Ecological analysis	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable verification	authors reported increased neurodevelopmental disorder incidence with higher cumulative thimerosal exposure, citing ~2–6× increases with an additional 75–100 µg Hg; design limits causal inference.	RR range ≈2–6× higher with higher Hg dose (graphical, dose–response); no single pooled

								OR tabulated
Westphal, G, 2000	Aluminum/thimerosal	Case-control	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	GSTM1 null was significantly more frequent in thimerosal-sensitized cases (65.9%) than in healthy controls (49.1%)	OR 3.1 (1.4–6.5) for combined GSTM1/T1 deletions and thimerosal sensitization, but this is a dermatologic allergy outcome
Stubbs, E, 1976	Vaccination	Case-control	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	5 of 13 autistic children who had documented prior rubella vaccination showed undetectable HI titers at baseline, whereas all 8 controls had detectable titers. Authors interpret this as suggesting a possible altered immune response in a subset of autistic children.	NR
Delong G, 2011	Vaccination	Ecological study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	results support further study of vaccine–autism links, while noting the ecological design shows association, not causation, and unmeasured state factors may remain.	Per 1% increase in vaccination rate by age 2 y, +680 additional children with AUT or SLI (state-level regression).
Klein NP, Fireman B, Yih WK, et al, 2010	Vaccination	Cohort study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	In 12–23-month-olds, first-dose MMRV carries about 2× the short-term (7–10 day) febrile-seizure risk compared with separate MMR + varicella; the absolute excess risk is small (≈1 per 2,300 doses)	RR 1.98 (1.43–2.73) for days 7–10 after MMRV vs MMR+V; excess 4.3 per 10,000 doses; ≈ 1 extra FS per

								2,300 MMRV doses vs MMR+V
Stajich GV, Lopez GP, Harry SW, Sexson WR, 2000	Vaccination	Pre/post study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Premature/low-birth-weight infants receiving thimerosal-containing HepB showed higher peak blood mercury relative to body weight; PK/safety signal	NR
Singh VK, Lin SX, Yang VC, 1998	Vaccination	Case-control	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Serologic/autoimmune study: elevated measles virus antibodies and anti-MBP reactivity reported in some autistic children; vaccination status not established;	NR
Feenstra B, Pasternak B, Geller F, Carstensen L, Wang T, Huang F, et al, 2014	Vaccination	Cohort study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Two innate-immune/virus-response loci (IFI44L, CD46) are specifically tied to MMR-proximate FS, while neuronal excitability genes (SCN1A, SCN2A, TMEM16C/ANO3) underlie FS risk overall	NR
Young HA, Geier DA, Geier MR, 2008	Aluminum/thimerosal	VSD Analysis	Not reported	Autism/ASD-related outcome (as per title)	Adverse event reports (VAERS; self/clinician-reported, unverified)	Reported vaccination in VAERS (unverified)	reported positive associations between infant ethyl-Hg exposure from thimerosal-containing vaccines and several neurodevelopmental disorders including autism; dose-dependent patterns across exposure windows; specific ASD ORs not detailed in abstract.	ASD: 3.67 per 1,000 NDD: 9.48 per 1,000
Schultz ST, Klonoff-Cohen HS, Wingard DL, Akshoomoff NA, Macer	Vaccination	Case-control	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Acetaminophen after MMR was associated with autistic disorder: Age ≤5 y: OR 6.11 (95% CI 1.42–26.3). Cases limited to regression: OR 3.97 (95% CI 1.11–14.3). Children with	Acetaminophen after MMR: OR 6.11 (1.42–26.3) in ≤5 y; regressive ASD: OR 3.97 (1.11–

a CA, Ji M, 2008							post-MMR sequelae: OR 8.23 (95% CI 1.56–43.3).	14.3); post-vax sequelae subset: OR 8.23 (1.56–43.3).
Holmes AS, Blaxill MF, Haley BE, 2003	Aluminum/thimerosal	Case-control	94 children with ASD	Autism/ASD-related outcome (as per title)	Not applicable	Not applicable	The mothers in the autistic group had significantly higher levels of mercury exposure through Rho D immunoglobulin injections and amalgam fillings than control mothers.	NR
Jablonowski and Hooker (2025)	MMR vaccination (timing/exposure per original population cohort)	Cohort	Not stated	Not stated	Not stated (original cohort used EHR/registry diagnostic codes)	Not stated (relies on original registry cohort)	Secondary analysis of an existing population-based MMR–autism study; reports association signals.	Overall NDD: 0.973 per 1,000 and ASD: 0.449 per 1,000
Geier DA, Geier MR. 2004	MMR immunization; mercury dose from thimerosal-containing childhood vaccines (e.g., DTP, Hib, pediatric Hep-B)	Ecological/time-trend comparative study using national administrative datasets	U.S. birth cohorts (late 1980s–mid-1990s); data drawn from CDC Biological Surveillance Summaries, U.S. Dept. of Education autism counts, and CDC live-birth estimates	Autism prevalence (administrative prevalence)	U.S. Dept. of Education special-education classification (administrative counts), not clinical confirmation	CDC Biological Surveillance Summaries and CDC live-birth estimates (national distributions/coverage; not individual records)	Reported a close correlation between estimated mercury dose from thimerosal-containing vaccines and autism prevalence (late 1980s–mid-1990s); a potential correlation for number of measles-containing vaccine doses and autism in the 1980s; "statistically significant" ORs vs. 1984 baseline and authors' claim that thimerosal contribution was >50% of observed effect	1.023 per µg Hg (≈+2.3% per µg); authors also note ~6-fold rise in reported prevalence 1981–1996K
Seneff S, Davidson RM, Liu J, 2012	Aluminum-containing vaccines (e.g., Hep-B, HiB Titer, DTaP, pneumococcal) and co-exposure to acetaminophen; MMR considered re: post-vaccination acetaminophen use	Retrospective study	U.S. VAERS reports (focus on children <6 years) 1990–2010; U.S. autism time-series from public sources	Autism mentions/time trends	VAERS text fields containing "autism"/"autistic"; public surveillance/prevalence sources; no individual clinical confirmation	VAERS vaccine-type coding; schedule context (e.g., added aluminum-containing pneumococcal doses post-1999 increasing aluminum burden)	analyses support a link between autism and aluminum in vaccines and suggest post-MMR acetaminophen use could contribute in susceptible children	NR

Jablonowski & Hooker, 2025	Aluminum Vaccines	secondary analysis/critique of a nationwide register-based cohort	Danish nationwide cohort, 1,224,176 children; births 1997–2018; follow-up from age 2	Autism/ASD-related outcome	Registry diagnoses from Danish national health registers	Danish National Health Service Register	Implies positive associations between aluminum exposure and NDDs; also highlights discrepancies between original vs updated supplements. It cites Andersson et al.'s adjusted hazard ratios per 1 mg Al showing aHR < 1 for NDDs and ASD, and presents additional counts/risk-difference style comparisons between dose strata.	overall NDD 0.973 per 1,000, autistic disorder 0.973 per 1,000
Christian LM, Iams JD, Porter K, Glaser R, 2011	Seasonal trivalent influenza vaccine (TIV) in pregnancy	Prospective pre–post observational (baseline; 1, 2, ~7 days post-TIV); inflammatory biomarkers	Pregnant women, **n=46** (1-day n=15; 2-day n=10; ~7-day n=21)	**Not applicable** (biomarker response study; no child outcomes)	Not applicable	Study-administered/documented TIV; clinic/record verification	**CRP** ↑ at 1 & 2 days ($p<.05$); **TNF-α** ↑ trend at 2 days ($p=0.06$); **large inter-individual variability** in cytokine responses (CV ~122–728%; greatest for IL-6 at 2 days); response milder/transient vs infection; informative for maternal immune activation	NR
Terhune TD, Deth RC, 2014	Mechanistic / animal / in vitro	Narrative review	ASD	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Hypothesis/review on impaired T-reg function and thimerosal as a potential contributor to neuroinflammation in ASD. No original human ASD outcomes.	NR
Palmer RF, Blanchard S, Stein Z, Mandell D,	Mercury	Ecological study	Not reported	Autism/ASD-related	Not applicable	Not applicable	Autism model: For each 1,000 lb increase in	+61% autism rate per 1,000 lb

Miller C, 2006				outcome			county-level mercury released, autism rate was 61% higher (RR 1.614; 95% CI 1.487–1.752). With additional adjustment for special-education count, the mercury term remained positive (RR 1.174; 95% CI 1.103–1.249)	of environmentally released mercury (Poisson models adjusted); special-ed rate +43%
Palmer RF, Blanchard S, Wood R, 2009	Mercury	Ecological, cross-sectional study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Study related to thimerosal/ethyl-mercury exposure and ASD	2.0 per 1,000
Stamova B, Green PG, Tian Y, et al, 2011	Mercury	Case-control study	2–5-year-old boys (autism n = n/r, typically developing controls n = n/r); RNA from peripheral blood	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Whole-genome expression profiling revealed distinct correlations between gene expression and blood mercury levels in AU vs TD boys. Of 26 genes correlated with mercury in both groups, 11 showed significantly different relationships ($p \leq 0.05$). 316 genes correlated with mercury only in TD and 189 only in AU. Differentially enriched pathways included cell death, cell morphology, amino acid metabolism, and antigen presentation, indicating divergent transcriptional responses to low-level	NR

							mercury exposure in autism.	
Ryu M-O, Kim H-S, Kim S-Y, et al, 2017	Prenatal and early childhood mercury exposure (blood and cord concentrations)	Cohort	458 mother–child pairs enrolled 2006–2010; serial blood Hg measurements (early/late pregnancy, cord, 2 y, 3 y)	Autistic behaviors at age 5	Social Responsiveness Scale (SRS)	Not applicable	Doubling of blood mercury at late pregnancy, cord blood, and ages 2–3 y was associated with higher SRS T-scores at age 5 (β = 1.84–2.80; $p < 0.05$). Elevated Hg at late pregnancy and cord blood predicted ≥60 SRS scores (RR = 1.31 [1.08–1.60] and RR = 1.28 [1.01–1.63], respectively). Findings indicate that prenatal and early-life mercury exposure is linked to increased autistic behaviors.	RR 1.31 (1.13–1.52) for SRS≥60; RR 1.28 (1.09–1.52) for SRS≥65 (per doubling blood Hg)
DeSoto MC, Hitlan RT, 2007	Mercury	Reanalysis of Case-Control	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Re-analysis of Ip et al. (2004) blood Hg dataset: reported a statistically significant Hg–ASD association after recalculation; findings contested.	NR
Institute of Medicine (US) Committee to Review the Adverse Consequences of Pertussis and Rubella Vaccines, Howson CP, Howe CJ, Fineberg HV, eds, 1991	Vaccination	Evidence-based consensus committee review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Review article on vaccination-related exposures; summarizes laboratory and clinical literature and discusses proposed mechanisms; does not calculate a new ASD risk estimate.	NR

Angrand L, Masson J-D, Rubio-Casillas A,Nosten-Bertrand M,Crépeaux G, 2022	Aluminum adjuvants	Narrative Review	Not reported	Autism /ASD-related outcome	Not applicable	Not applicable	Review proposing that inflammation and impaired autophagy could be convergent pathways by which aluminum adjuvants might influence neurodevelopment; no new human ASD effect sizes.	NR
Mostafa GA, Bjørklund G, Urbina MA, Al-Ayadhi LY, 2016	Blood mercury concentration	Case-control	84 children with ASD (3–10 y) and 84 age- and sex-matched controls	Autism /ASD-related outcome (as per title)	Childhood Autism Rating Scale (CARS)	Not applicable	ASD children showed significantly higher blood mercury and serum neurokinin A (NKA) levels than controls ($p < 0.001$). NKA and mercury levels were positively correlated with CARS severity scores. Among ASD cases with elevated NKA, 78.3% also had elevated blood mercury ($p < 0.001$). Findings suggest that mercury-related neuroinflammation, marked by increased NKA, may contribute to ASD pathophysiology.	78.3% of ASD children with ↑ NKA had ↑ Hg; positive linear correlations between CARS, NKA, and BHg ($p < 0.001$)
Burbacher TM, Shen DD, Liberato N, Grant KS, Cernichiari E, Clarkson T, 2005	Thimerosal	Controlled experimental study	Not reported	Autism /ASD-related outcome	Not applicable	Not applicable	Infant macaque pharmacokinetics: ethylmercury from thimerosal cleared blood faster than methylmercury; more inorganic Hg detected in	NR

							brain despite lower total Hg;	
Alberto Boretti, 2021	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Review article on vaccination-related exposures; summarizes laboratory and clinical literature and discusses proposed mechanisms; does not calculate a new ASD risk estimate.	NR
Lukiw WJ, Percy ME, Kruck TP, 2005	Vaccination	Experimental Study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	In primary human neural cells, exposure to 100 nM aluminum sulfate altered gene expression on whole-genome microarrays.	NR
Petrik MS, Wong MC, Tabata RC, Garry RF, Shaw CA, 2007	Aluminum Adjuvant	Experimental study	young adult male CD-1 mice	Autism/ASD-related outcome	Not applicable	Not applicable	Authors conclude aluminum adjuvant exposure can produce motor deficits and motor-neuron pathology in mice.	NR
Carvalho CM, Lu J, Zhang X, Arnér ES, Holmgren A, 2011	Aluminum/thimerosal	Experimental Study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Mercury potently inhibits mammalian thioredoxin reductase (TrxR)	NR
Rice DC, 1989	Aluminum/thimerosal	Experimental Study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Quantified total Hg in multiple tissues/brain regions and inferred brain vs blood half-life under chronic dosing conditions	NR
Olczak M, Duszczyk M, Mierzejewski P, Meyza K, Majewska MD, 2011	Aluminum/thimerosal	Experimental Study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Follow-up rodent work reported persistent neurochemical changes after early thimerosal exposure; animal study.	NR

Lyons-Weiler J., 2022	Vaccination	Secondary analysis	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Review article on vaccination-related exposures; summarizes laboratory and clinical literature and discusses proposed mechanisms; does not calculate a new ASD risk estimate.	NR
Terhune TD, Deth RC, 2018	Aluminum/thimerosal	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	aluminum-adjuvanted vaccines may amplify Th2-skewed immunity and contribute to eosinophilia/allergic disease in a genetically susceptible subpopulation	Nr
Min Heui Yoo, Tae-Youn Kim et al., 2025	Aluminum/thimerosal	Not reported	Not reported	Autism/ASD-related outcome (as per title)	Clinical/registry diagnosis (not otherwise specified)	Not applicable (no vaccination exposure measured)	Study related to aluminum-adjuvant immunology/toxicology, thimerosal/ethyl-mercury exposure and ASD.	NR
Marcos V.S. Sales, 2024	Vaccination	Experimental Study	21-day-old Wistar rats	Autism/ASD-related outcome	Not applicable	Not applicable	Acute thimerosal exposure in this infant-rat model disrupted brain bioenergetic pathways and preferentially affected nervous tissue	NR
Goldman GS, 2022	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Narrative critique alleging outcome-reporting bias in selected vaccine safety studies; calls for greater transparency; provides no new autism risk estimates.	NR
Matthew Mold et al, 2018	Vaccination	Post-mortem quantification + histology	ASD donors	Autism/ASD-related outcome	Not applicable	Not applicable	Post-mortem brain study (n≈5 ASD donors) reported high aluminum concentration	NR

							s in several regions	
Mold M, Exley C, 2020	Vaccination	Post-mortem quantification	ASD donors	Autism/ASD-related outcome	Postmortem donors with pre-existing ASD diagnosis in brain bank/medical records	Not applicable	Post-mortem microscopy/chemistry describing aluminum in brain tissue from ASD cases.	NR
Girolamo, Giannotta & Nicola, Giannotta. 2022	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Vaccine-induced peripheral pro-inflammatory cytokines (e.g., IL-1β, IL-6, TNF-α) can reach the brain, activate microglia, and cause neuroinflammation in susceptible individuals.	NR
DeSoto MC, Hitlan RT, 2010	Aluminum/thimerosal	Narrative review	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Of 58 empirical papers, 43 were judged to support a link between ASD and heavy-metal exposure.	NR
Mold M, Umar D, King A, Exley C, 2017	Vaccination	Post-mortem quantification	ASD donors	Autism/ASD-related outcome	Postmortem donors with pre-existing ASD diagnosis in brain bank/medical records	Not stated	This series reports “extraordinarily high” aluminium content in ASD brains and posits that its cellular localisation in inflammatory cells may be relevant to ASD pathophysiology	NR
Morris G, Puri BK, Frye RE, 2017	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	“Significant quantities” of aluminium introduced via immunisation could plausibly produce chronic neuropathology in genetically susceptible children	NR
James SJ, Slikker W 3rd, Melnyk	Vaccination	Experimental Study	Not reported	Autism/ASD-related	Not applicable	Not applicable	Thimerosal exposure depleted	NR

S, New E, Pogribna M, Jernigan S. 2005				outcome			intracellular GSH in both cell types; cytotoxicity tracked with this depletion.	
Risher JF, Tucker P, 2017	Aluminum/thimerosal	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	MeHg and EtHg share broadly similar toxic mechanisms; differences in observed toxicity likely reflect exposure, metabolism, and elimination	NR
Goth SR, Chu RA, Gregg JP, Cherednichenko G, Pessah IN, 2006	Vaccination	Mechanistic study	Not reported	Autism/ASD-related outcome	Not stated	Not stated	Dendritic cells are highly sensitive to nanomolar thimerosal	NR
Blaxill MF, Redwood L, Bernard S, 2004	Aluminum/thimerosal	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Narrative/advocacy review arguing thimerosal–ASD link; not primary epidemiology.	NR
Piyasirisilp S, Hemachudha T, 2002	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Review/case reports of post-vaccination neurologic events	NR
Gold MS, 2002	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Review of vaccine adverse events and surveillance	NR
Bernard S, Enayati A, Redwood L, Roger H, Binstock T, 2001	Aluminum/thimerosal	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	authors propose that many cases of idiopathic autism are induced by early mercury (thimerosal) exposure, representing an unrecognized mercurial syndrome, with genetic and non-genetic susceptibility determining which children are affected	NR
Kawashima H, Mori T, Kashiwagi Y,	Measles virus (wild-type vs vaccine	case–control study	Humans: 8 Crohn's disease, 3	Not an incidence/risk	NR (children described as having	"Exposure history" referenced; specific verification method	MV RNA detected in PBMCs of	NR

Takekuma K, Hoshika A, Wakefield A, 2000	strain; context of MMR)		ulcerative colitis, 9 children with autism + GI disease ("autistic enterocolitis"); controls: 8 (healthy children and patients with SSPE, SLE, HIV-1)	study; ASD cases only	autism with GI symptoms)	NR in abstract (inference: clinical/record history)	3/9 autistic children, 1/8 Crohn's, 1/3 UC; all controls negative. Sequences: Crohn's case resembled wild-type; UC and autism positives were consistent with vaccine strain; findings aligned with each patient's exposure history.	
J.S. Charleston et al., 1994	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	suggests inorganic Hg may be a key driver of the reactive gliosis, which persists after MeHg cessation.	Reactive glia ↑72% (6 mo), ↑152% (12 mo), ↑120% (18 mo); clearance group ↑89%; inorganic Hg group ↑165% reactive glia
Jafari T, Rostampour N, Fallah AA, Hesami A, 2017	Aluminum/thimerosal	Systematic Review/ Meta analysis	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Results suggest impaired detoxification /excretion in ASD and state that mercury is an "important causal factor" in ASD etiology	Whole blood Hg: Hedges g = 0.43 (95% CI 0.12–0.74); RBC Hg: g = 1.61 (0.83–2.38); Brain Hg: +0.61 ng/g (0.02–1.19); Hair Hg lower: −0.14 mg/g (−0.28 to −0.01)
Yassa HA, 2014	Aluminum/thimerosal	Case-control	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	The paper asserts that lead and mercury are among the main causes of autism and that chelation plays a major role in improving symptoms.	NR

Shaw CA, Seneff S, Kette SD, Tomljenovic L, Oller JW Jr, Davidson RM, 2014	Aluminum/thimerosal	Narrative Review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Concludes that human CNS disorders may serve as sensitive indicators of Al toxicant exposures; calls for heightened scrutiny of Al in medicine/industry	NR
Li X, Qu F, Xie W, et al, 2014	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	High-dose neonatal thimerosal can induce persistent changes in neurodevelopment, synaptic pathways, and endocrine systems, coinciding with autistic-like and depression-like behaviors in mice	NR
Shaw CA, Li Y, Tomljenovic L, 2013	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Results negatively affected weight gain, anxiety, and locomotion due to high levels of Al	NR
Mary Holland, Louis Conte, Robert Krakow, and Lisa Colin, 2011	Vaccination	Case review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Identified 83 VICP-compensated cases of vaccine-induced brain injury that included autism or autism-like symptoms	83 cases of acknowledged vaccine-induced brain injury that include autism (21 published decisions; 62 settlements).
Herdman ML, Marcelo A, Huang Y, Niles RM, Dhar S, Kiningham KK, 2006	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Blocking c-Jun with TAM67 lowered AP-1 activity but did not blunt apoptotic signaling, suggesting thimerosal triggers JNK-mediated apoptosis	NR

							independent of c-Jun	
Waly M, Olteanu H, Banerjee R, et al, 2004	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Biochemical study: oxidative stress/methylation pathway abnormalities (methionine synthase) in ASD	NR
Baskin DS, Ngo H, Didenko VV, 2003	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	In-vitro neuronal models: thimerosal exposure induced apoptosis/DNA fragmentation; mechanistic only	NR
Weibel RE, Caserta V, Benor DE, Evans G, 1998	Further-attenuated measles–containing vaccines (monovalent measles: Attenuvax, Lirugen; combined MR: M-R-Vax/M-R-Vax II; combined MMR: M-M-R/M-M-R II). Monovalent mumps (Mumpsvax) and rubella (Meruvax/Meruvax II) also reviewed.	Retrospective review of National Vaccine Injury Compensation Program (NVICP) claims; case series with time-to-onset analysis	Children aged 10–49 months who received a first dose between 1970–1993 and developed acute encephalopathy with no determined cause within 15 days; n=48 met inclusion; 8 deaths	Autism/ASD-related outcome	NR	NR	The day 8–9 clustering suggests a possible causal relationship between measles-containing vaccines and acute encephalopathy as a rare complication of immunization	NR
Deisher TA, Doan NV, Koyama K, Bwabye S, 2015	Vaccines manufactured in human fetal cell lines (e.g., MMR II via rubella component; Meruvax II [rubella]; Havrix [Hepatitis A]); broader framing as "fetal-cell-line manufactured vaccines"	Mixed design: ecological (country-level MMR coverage vs ASD prevalence trends in UK, Norway, Sweden) + laboratory assays (DNA quantification in vaccine vials; in-	Ecological: national data (MMR coverage and ASD/AD prevalence) for the UK, Norway, Sweden. Lab: vials of Meruvax II and Havrix; human cell lines HFF1 and NCCIT for uptake; genomic analysis of autism-associated genes	ASD prevalence trends (drop after birth year 1998, rise after ~2000, per authors' description)	Registry/surveillance prevalence data compiled from public/government sources and literature	National immunization coverage from government sources/registries	Reported fetal DNA fragments in Meruvax II (~215 bp; mean ssDNA 142 ng/vial; dsDNA 35 ng/vial) and Havrix (ssDNA ~276 ng/vial; dsDNA ~35.7 ng/vial); observed DNA uptake into HFF1/NCCIT cells; argue the "Wakefield scare" created a natural experiment where	NR

		vitro DNA uptake) + in-silico genomic analysis					reduced MMR coverage coincided with lower ASD prevalence, with later rebound; propose insertional mutagenesis as a mechanism	
Yel L, Brown LE, Su K, Gollapudi S, Gupta S, 2005	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Thimerosal triggered apoptosis via the mitochondrial (intrinsic) pathway	NR
Mutter J, Naumann J, Schneider R, Walach H, Haley B, 2005	Aluminum/thimerosal	Narrative Review	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Argue autism's rise parallels increasing mercury exposure; note U.S. infants in the 1990s could receive ~187.5 µg ethylmercury by 6 months via thimerosal-containing vaccines	NR
Migdal C, Foggia L, Tailhardat M, Courtellemont P, Haftek M, Serres M, 2010	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Thimerosal acts as a pro-sensitizing agent in vitro by triggering mitochondria-driven oxidative stress	NR
Sharpe MA, Livingston AD, Baskin DS, 2012	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	In-vitro astrocyte/neuronal models: ethyl-Hg impaired mitochondrial function and increased oxidative stress; mechanistic only	NR
Hamza H, Cao J, Li X, Li C, Zhu M, Zhao S, 2012	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Apoptosis-gene transcripts (CASP7/9, ICAD, ROCK1, APAF1) were dose- and time-dependently upregulated	NR

Sulkowski ZL, Chen T, Midha S, Zavacki AM, Sajdel-Sulkowska EM, 2012	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Rat model: neonatal thimerosal exposure produced cerebellar oxidative stress/behavioral changes (male-biased). Animal findings; not evidence of human ASD risk.	NR
Duszczyk-Budhathoki M, Olczak M, Lehner M, Majewska MD, 2012	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Neonatal thimerosal (240 µg Hg/kg ×4) produced persistent increases in extracellular glutamate and aspartate in adult PFC (10–14 weeks later), with decreases in glycine and alanine.	NR
Dórea JG, 2011	Aluminum/thimerosal	Narrative review	Autism/ASD	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Given these experimental signals, continued use of thimerosal in infant vaccines warrants evaluation of a sufficiently non-toxic exposure level, particularly with repeated early-life dosing	NR
Rooney JPK, 2014	Aluminum/thimerosal	Systematic review	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Evidence points to a brain half-life for inorganic Hg of several years to several decades, with implications for PBPK modeling and regulatory toxicology	NR
Tomljenovic L, Shaw CA, 2011	Vaccination	Narrative review	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	ASD prevalence correlated strongly with estimated cumulative Al exposure from vaccines 1991–2008 (r	USA time-series: r=0.92 (p<0.0001). Seven countries (3–4 mo dose

							= 0.92, p<0.0001; 95% CI 0.79–0.97). ASD prevalence also correlated with the yearly number of Al-adjuvanted vaccines (r = 0.90, p<0.0001; R^2 = 0.82)	window): r=0.89–0.94 (p=0.0018–0.0248
Kempuraj D, Asadi S, Zhang B, et al, 2010	Aluminum/thimerosal	Mechanistic study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Inorganic mercury at sub-cytotoxic concentrations can activate human mast cells to release VEGF and IL-6, potentially affecting barrier integrity (e.g., BBB) and contributing to neuroinflammatory mechanisms	NR
Olczak M, Duszczyk M, Mierzejewski P, Majewska MD, 2009	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Rodent model of repeated neonatal thimerosal exposure reported neuropathological and neurotransmitter alterations	NR
Ekstrand J, Nielsen JB, Havarinasab S, Zalups RK, Söderkvist P, Hultman P, 2010	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Mercury retention and tissue distribution vary markedly by mouse strain and sex, with kidneys driving persistent body burden in high-retaining genotypes—implicating multiple non-H-2 genetic factors in susceptibility.	NR
Minami T, Miyata E, Sakamoto Y, Yamazaki H, Ichida S, 2010	Aluminum/thimerosal	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	The cerebellum is more sensitive to thimerosal than	NR

							cerebrum (greater/earlier MT responses). Because brain Hg was undetectable at a “clinical” dose, MT induction served as biological evidence that thimerosal penetrated/affected brain tissue.	
Branch DR, 2009	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Preliminary but first report of sex-dependent thimerosal toxicity in this model; future toxicology studies should account for sex as a biological variable.	NR
Carvalho CM, Chew EH, Hashemy SI, Lu J, Holmgren A, 2008	Aluminum/thimerosal	Mechanistic study	Not reported	Autism/ASD-related outcome	Clinical/registry diagnosis	Not applicable	Mercury compounds selectively disable the cellular thioredoxin system—especially TrxR—at very low (nanomolar) concentrations, with downstream implications for redox balance and stress responses.	NR
Wu X, Liang H, O'Hara KA, Yalowich JC, Hasinoff BB, 2008	In-vitro mechanistic	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Thimerosal induced single- and double-strand DNA breaks in K562 cells, consistent with rapid apoptotic responses.	NR
Kern JK, Jones AM, 2006	Mechanistic / animal / in vitro	Narrative review	ASD	Evidence of toxicity, oxidative stress, and neuronal	Varies by paper; often secondary analyses/surveys or environmental biomarkers; no standardized	No vaccination verification (exposure not verified from records in these works).	Study related to vaccination-related exposures and ASD; based on the available details, the paper does	NR

				insult in autism	new ASD verification reported here.		not report a new individual-level vaccine–ASD effect estimate.	
Walker SJ, Segal J, Aschner M, 2006	Vaccination	Experimental study	Not reported	Autism/ASD-related outcome	Not applicable	Not applicable	Prominent up-regulation of multiple HSP transcripts, not MTs—indicating a distinct stress-response program vs zinc	NR
Robert Oldham Young, 2025	Vaccination	Comprehensive Review	ASD	Autism/ASD-related outcome	Not applicable	Not applicable	This paper reviews evidence supporting associations between vaccines and autism-related medical conditions, focusing on mechanisms such as immune dysregulation, neuroinflammation, toxicological impacts of vaccine components like aluminum and mercury, and the effects of cumulative vaccine schedules.	NR