Supplemental Table 1 International Classification of Diseases (ICD), eighth (ICD-8; 1969–1986), ninth (ICD-9; 1987–1996), and tenth (ICD-10; 1997–2013) revisions codes for diagnoses used in this study

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Specific subtypes | **ICD-8** | **ICD-9** | **ICD-10** |
| **All psychiatric disorders** |  | 290-315 | 290-315 | F |
| **Subtypes of psychiatric disorders** |  |  |  |  |
| Neurodevelopmental disorders | Attention-deficit hyperactivity disorder | - | 314 | F90 |
| Autism spectrum disorder | – | 299 | F84 |
| Intellectual disability | 310-315 | 317-319 | F70-F79 |
| Emotional disorders | Mood disorders, *mainly including depressive disorder and bipolar disorder* | 296, 300.4 | 296, 300E, 311 | F30-F39 |
| Anxiety disorders | 300.0, 300.2 | 300A, 300C | F40-F41 |
| Stress-related disorder | 307, 308.4 | 308, 309 | F43 |
| Behavioral and emotional disorders with onset usually occurring in childhood and adolescence | - | 312, 313 | F91-F98 |
| Other psychiatric disorders |  | 290–315, but not in the any of above categories | 290–315, but not in the any of above categories | F, but not in the any of above categories |
| **Congenital malformations, deformations and chromosomal abnormalities** | | 740-759 | 740-759 | Q |
| **Severe somatic diseases** | Myocardial infarction | 410 | 410,412 | I21, I22, I25.2 |
| Congestive heart failure | 427.00-427.27, 428.99 | 428 | I50 |
| Cerebrovascular disease | 430-438 | 430-438 | G45, G46, I60-I69 |
| Chronic pulmonary disease | 460-466, 490-493, 502-508 | 490-496 | J40-J47 |
| Connective tissue disease | 710-718 | 710A, 710B, 710E, 714A, 714B, 714C, 714W,714X, 725 | M05, M06, M32-M34, M35.1, M35.3 |
| Diabetes | 250.00 | 250 | E10-E14 |
| Renal diseases | 580-584, 590 | 582,583 | N01, N03, N05.2-N05.7 |
| Liver diseases | 570-576 | 571C, 571E,571F, 571G, 572C, 572D, 572E, 572W, 456A, 456B, 456C | K70.2-K70.4, K71.7, K72.1, K72.9, K73, K74, K76.6, K76.7 |
| Ulcer diseases | 530.93, 531-534 | 531-534 | K25-K28 |
| HIV infection/AIDS | - | 042-044 | B20-B24 |

Supplementary Table 2 Hazard ratios (HRs) with 95% confidence intervals (CIs) for any psychiatric disorder among twins who lose a co-twin at birth, calculated separately for older and younger siblings of the surviving twins, sub-groups by psychiatric disorders among parents during follow-up

|  | **Population-based matched cohort** | | | | **Twin-sibling family cohort** | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Number of cases (Crude incidence rate, per 1000 person years), exposed **twins**/unexposed **twins** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), exposed **twins** /matched **singletons** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), exposed **twins**/**full siblings** | HR(95% CI) † |
| ***By birth order of the full siblings*** |  |  |  |  |  |  |
| Surviving twins vs. their older siblings | - | - | - | - | 61(11.92)/50(6.97) | 1.74 (0.54-5.59) |
| Surviving twins vs. their younger siblings | - | - | - | - | 90(12.21)/80(9.15) | 1.27 (0.48-3.34) |
| ***By psychiatric disorders among parents during follow-up*** |  |  |  |  |  |  |
| Yes | 29(9.78)/104(6.34) | 1.36 (0.71-2.61) | 29(9.78)/139(8.24) | 1.83 (0.88-3.80) | 22(11.63)/26(8.66) | 1.26 (0.17-9.38) |
| No | 149(12.67)/496(8.14) | 1.53 (1.24-1.87) | 149(12.67)/584(9.65) | 1.42 (1.16-1.73) | 108(12.48)/104(8.06) | 1.74 (0.85-3.58) |
| ***By diagnosis of congenital abnormalities*** |  |  |  |  |  |  |
| Yes | 54(20.42)/165(14.64) | 1.62 (1.03-2.55) | 54(20.42)/174(14.83) | 2.54 (1.45-4.45) | 40(21.13)/8(8.52) | - |
| No | 124(10.26)/435(6.58) | 1.63 (1.30-2.03) | 124(10.26)/549(8.36) | 1.33 (1.07-1.65) | 90(10.40)/122(8.15) | 1.49 (0.71-3.14) |
| ***By the presence of severe somatic diseases during follow-up*** |  |  |  |  |  |  |
| Yes | 46(14.89)/90(9.52) | 1.88 (0.82-4.30) | 46(14.71)/170(12.79) | 1.41 (0.78-2.54) | 31(13.84)/16(9.17) | - |
| No | 132(11.34)/510(7.51) | 1.58 (1.27-1.95) | 132(11.38)/553(8.62) | 1.40 (1.13-1.73) | 99(11.92)/114(8.05) | 1.26 (0.59-2.66) |
| ***Additionally adjusted for diagnosis of congenital abnormalities and severe somatic diseases during follow-up*** | 178(12.08)/600(7.76) | 1.53(1.28-1.84) | 178(12.08)/723(9.33) | 1.39(1.17-1.66) | 130(12.32)/130(8.17) | 1.26(0.69-2.31) |

\* Cox regression models were stratified by matching identifiers (sex, birth year, and gestational age), and adjusted for birth weight for gestational age, maternal age at childbirth, low Apgar score ≤7 at 5/10 min, maternal education level at childbirth, maternal cohabitation status during pregnancy, and family history of psychiatric disorder.

† Cox regression models were stratified by matching identifiers (sex, birth year, gestational age, birth weight for gestational age, birth order), and adjusted for maternal age at childbirth, low Apgar score ≤7 at 5/10 min, maternal education level at childbirth, maternal cohabitation status during pregnancy, and family history of psychiatric disorder.

Supplementary Table 3 Hazard ratios (HRs) with 95% confidence intervals (CIs) for any psychiatric disorder among twins who lose a co-twin at birth, sub-grouped by or additionally adjusted for diagnosis of congenital abnormalities and severe somatic diseases during follow-up

|  | **Population-based matched cohort** | | | | **Twin-sibling family cohort** | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Number of cases (Crude incidence rate, per 1000 person years), exposed **twins**/unexposed **twins** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), exposed **twins** /matched **singletons** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), exposed **twins**/**full siblings** | HR(95% CI) † |
| ***By diagnosis of congenital abnormalities*** |  |  |  |  |  |  |
| Yes | 54(20.42)/165(14.64) | 1.62 (1.03-2.55) | 54(20.42)/174(14.83) | 2.54 (1.45-4.45) | 40(21.13)/8(8.52) | - |
| No | 124(10.26)/435(6.58) | 1.63 (1.30-2.03) | 124(10.26)/549(8.36) | 1.33 (1.07-1.65) | 90(10.40)/122(8.15) | 1.49 (0.71-3.14) |
| ***By the presence of severe somatic diseases during follow-up*** |  |  |  |  |  |  |
| Yes | 46(14.89)/90(9.52) | 1.88 (0.82-4.30) | 46(14.71)/170(12.79) | 1.41 (0.78-2.54) | 31(13.84)/16(9.17) | - |
| No | 132(11.34)/510(7.51) | 1.58 (1.27-1.95) | 132(11.38)/553(8.62) | 1.40 (1.13-1.73) | 99(11.92)/114(8.05) | 1.26 (0.59-2.66) |
| ***Additionally adjusted for diagnosis of*** ***congenital*** ***abnormalities and severe somatic diseases during follow-up*** | 178(12.08)/600(7.76) | 1.53(1.28-1.84) | 178(12.08)/723(9.33) | 1.39(1.17-1.66) | 130(12.32)/130(8.17) | 1.26(0.69-2.31) |

\* Cox regression models were stratified by matching identifiers (sex, birth year, and gestational age), and adjusted for birth weight for gestational age, maternal age at childbirth, low Apgar score ≤7 at 5/10 min, maternal education level at childbirth, maternal cohabitation status during pregnancy, and family history of psychiatric disorder.

† Cox regression models were stratified by matching identifiers (sex, birth year, gestational age, birth weight for gestational age, birth order), and adjusted for maternal age at childbirth, low Apgar score ≤7 at 5/10 min, maternal education level at childbirth, maternal cohabitation status during pregnancy, and family history of psychiatric disorder.

Supplementary Table 4 Hazard ratios (HRs) with 95% confidence intervals (CIs) for any psychiatric disorder among twins who lost a co-twin **within 28 days after birth**, derived from different Cox models and by subtypes of psychiatric disorders

|  | **Population-based matched cohort** | | | | | **Twin-sibling family cohort** | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Number of cases (Crude incidence rate, per 1000 person years), exposed **twins**/unexposed **twins** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), exposed **twins** /matched **singletons** | HR(95% CI)\* | Number of cases (Crude incidence rate, per 1000 person years), **exposed twins/full siblings** | | HR(95% CI)\* |
| **Model information:**  **Model 1**  Controlled for attained age, (as underlying time scale), sex and all prenatal factors (i.e., GA, birth weight for GA maternal age at birth) | 159(12.00)/549(7.92) | 1.55 (1.28-1.87) | 159(12.00)/658(9.47) | 1.38 (1.15-1.66) | 117(12.29)/106(7.56) | | 1.81 (0.92-3.57) |
| **Model 2**  above + neonatal factors (Apgar score) | 1.52 (1.26-1.84) | 1.34 (1.11-1.60) | 1.74 (0.88-3.45) |
| **Model 3**  above + family history of psychiatric disorder, education level (mother); cohabitation status (mother) | 1.52 (1.25-1.84) | 1.38 (1.15-1.67) | - |
| ***Full adjusted HRs***† ***for subtypes of psychiatric disorders*** |  |  |  |  |  | |  |
| Neurodevelopment disorders (including ADHD, ASD, and intellectual disabilities ) | 67(4.76)/209(2.91) | 1.56 (1.16-2.12) | 67(4.76)/256 (3.53) | 1.44 (1.08-1.93) | 50(4.91)/26(1.78) | | 0.25 (0.02-2.91) |
| Emotional disorders (including depression, anxiety, stress-related disorder) | 94(6.73)/262(3.66) | 1.90 (1.46-2.46) | 94(6.73)/346 (4.82) | 1.57 (1.23-2.01) | 71(7.03)/71(4.96) | | 1.79 (0.76-4.23) |
| Other psychiatric disorders | 69(4.95)/280(3.95) | 1.17 (0.88-1.55) | 69(4.95)/327(4.58) | 1.15 (0.87-1.51) | 49(4.87)/47(3.26) | | 1.47 (0.50-4.37) |

GA, gestational age.

**\***Cox regression models were stratified by matching identifiers or family identifier, and adjusted for covariates mentioned in the ‘model information’ column. Attained age was applied as the underlying time scale.

†HRs were derived from fully adjusted Cox regression models, i.e., model 3.