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Perinatal Psychosocial Profiles and Offspring Longitudinal Cardiometabolic Risk Factors: A Latent Analysis Approach

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Abstract

Background/Objectives: Early-life exposures, including maternal psychosocial profile, can shape an individual's lifelong development. There is growing interest in the effects of prenatal exposures on cardiometabolic health through childhood. The present study used latent profile analysis to identify psychosocial profiles among pregnant women by examining the co-occurrence of personality traits, anxiety, depression, and social capital and compared them with offspring health outcomes. Methods: Latent analysis identified three distinct psychosocial profiles for 638 participants from the Rhea cohort, following the use of multiple imputation techniques, based on a total analytic sample of 1340 participants. Results: The "Normative" profile (51.2%) had near-zero scores across all standardised psychosocial indicators, representing the baseline group. The "Resilient-Socially Resourced" profile (28.7%) was characterised by low anxiety, neuroticism, and prenatal depression, and high extraversion and social engagement. The "Psychosocially Vulnerable" profile (20.1%) exhibited high anxiety, neuroticism, and prenatal depression, with low extraversion and social connectedness. Associations between maternal psychosocial profiles and offspring cardiometabolic outcomes at ages 4, 7, and 11 years were generally weak and inconsistent. On the contrary, latent socioeconomic classes showed larger effects. Children of "Younger and socioeconomically vulnerable individuals" showed a three-fold higher risk of hypertension at age 4, compared to those from "Professional and well-resourced families". Conclusions: Findings suggest that although distinct maternal psychosocial profiles can be identified, they may have limited influence on offspring cardiometabolic risk through mid-childhood. Further research is needed to clarify how psychosocial and socioeconomic exposures interact across the life course and influence offspring health trajectories.

Keywords: perinatal mental health; psychosocial functioning; latent profiles; child cardiometabolic risk factors

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1. Introduction

The Developmental Origins of Health and Disease (DOHaD) paradigm proposes that environmental exposures in utero and during the early postnatal period can shape

later health trajectories via the foetal programming hypothesis [1–3]. It refers to a broad range of non-genetic influences that can affect development through mechanisms such as epigenetic modification, altered organ development, and long-term changes in metabolic and physiological regulation. The DOHaD framework has historically emphasised the influence of maternal nutrition, metabolic status, and physical health conditions on offspring outcomes. In contrast, maternal psychological factors have received comparatively less attention [4], although this area of research is rapidly expanding. Emerging evidence supports that maternal stress and mood disorders engage biological systems by altering hypothalamic–pituitary–adrenal (HPA) axis activity, glucocorticoid signalling, inflammatory processes, and placental functioning, all of which are critical for foetal growth and neurodevelopment [5–7].

From conception through at least the early postnatal months, offspring development is influenced by maternal psychological functioning. Specific personality dimensions, depression, and anxiety symptoms during pregnancy, which have been linked to adverse birth outcomes [8–11], may also increase the risk for postpartum depression [12,13] and escalate nourishing difficulties [14,15]. Meta-analytic evidence further suggests associations with offspring outcomes across childhood and adolescence, but results regarding childhood cardiometabolic outcomes are diverse [16]. Relatively few longitudinal cohort studies have investigated associations with offspring physical growth, and findings are inconsistent. Maternal psychological distress has been associated with lower anthropometry [17] and delayed early development [18], while other studies report null or age-dependent effects [19,20]. Psychological factors, including parental distress and maternal depression, may contribute to childhood overweight [21,22]. Childhood overweight and obesity are rising worldwide, threatening future generations since obesity in childhood is linked to adverse health trajectories and increased risk of chronic diseases in adulthood [23]. Conditions such as obesity, diabetes, and cardiovascular disease may originate in early development [24].

On the other hand, social support is a well-established protective factor for maternal mental health during pregnancy. The stress-buffering hypothesis proposes that social support mitigates the negative effects of stressful experiences by enhancing coping resources and reducing psychological distress [25,26]. Moreover, social relationships affect health through behavioural, psychological, and physiological pathways, including stress-related neuroendocrine regulation [27]. This is especially relevant in pregnancy, as maternal stress can alter the intrauterine environment and influence offspring development. Consistent with this framework, a meta-analysis of 67 studies found that low social support in pregnancy was associated with higher antenatal depression, anxiety, and self-harm risk [28]. Evidence suggests that social capital and social network characteristics are associated with obesity and other cardiometabolic risk factors through their influence on health behaviours, social norms, and access to resources [29,30]. Social capital theory suggests that social networks, trusting relationships, and reciprocal exchanges are key determinants of health and well-being through mechanisms such as exposure to health-related norms, psychosocial resources, and access to material and informational support [31]. Social capital is typically conceptualised as comprising cognitive (e.g., trust, reciprocity, perceived cohesion) and structural (e.g., participation, network embodiment) dimensions, which may exert distinct influences on health outcomes. Furthermore, higher social capital has been associated with lower postpartum depressive symptoms, with evidence suggesting that this protective effect is mainly explained by cognitive rather than structural dimensions of social capital, particularly perceived value of life and social agency [32,33].

In light of these findings, the present study adopts a person-centred approach to identify latent psychosocial profiles among mothers during pregnancy, based on personality traits, anxiety, depression, and social capital, recognising that these components of

psychosocial functioning may interact, rather than operate independently [34]. Unlike traditional variable-centred analyses that examine individual psychosocial factors in isolation, latent profile analysis captures their co-occurring patterns and identifies distinct maternal subgroups with different psychosocial needs [35,36]. In addition, a secondary objective was to assess the association between selected maternal psychosocial and demographic factors during the perinatal period and child cardiometabolic risk factors.

To our knowledge, no published study has investigated the relationship between maternal psychosocial profiles during pregnancy and offspring cardiometabolic health later in life. This study aims to address key gaps in current scientific understanding by examining the influence of the early-life social environment on child risk factors in an existing population-based mother–child cohort in Crete, Greece.

2. Materials and Methods

2.1. Epidemiological and Clinical Data

The research drew longitudinal data from the well-established Rhea mother–child cohort study, which examines a population-based sample of pregnant women and their offspring, residents of the Prefecture of Heraklion, Crete, Greece [37]. Between February 2007 and January 2008, pregnant women attending a public hospital or a private clinic to perform their first major ultrasound examination were approached and informed of the study protocol. Only women with good understanding of the Greek language and at least 16 years of age were recruited. Structured face-to-face and telephone interviews, medical records, clinical examinations, and biological samples were used to collect important pregnancy data at baseline (12th–14th week of gestation), as well as at mid-pregnancy (28th–32nd week of gestation), at delivery, and postnatally at the 8th–10th week. Thereafter, their children were followed up at the 9th and 18th month, and at the 4th, 7th, 11th, and 15th year of age. All procedures complied with the ethical standards of the relevant institutional and/or national research committees, as well as with the Declaration of Helsinki and its subsequent amendments. The research protocols for the different phases of the cohort have been approved by the Ethical Committees of the University Hospital, the Health Authority of Crete, and the University of Crete. Written, informed consent was provided by all participants after complete description of the study at all phases and permission was granted to use these data in future analyses within the Rhea study framework.

2.1.1. Exposures Related to the Current Study

Maternal and paternal sociodemographic and lifestyle information has been collected at baseline and updated in later follow-ups. During the first interview, women reported information on education, employment, and marital and cohabitation status, as well as housing conditions and lifestyle habits, such as smoking, alcohol consumption, etc. Validated psychometric questionnaires were self-completed. Perinatal depressive symptoms were measured with the Edinburgh Postnatal Depression Scale [38] and anxiety with STAI-Trait [39]. Personality traits of neuroticism, extraversion, and psychoticism were assessed using Eysenck's Personality Questionnaire [40]. Finally, social capital dimensions of "Participation in the Community", "Feelings of Safety", "Tolerance of Diversity", and "Value of Life and Social Agency" were measured through the Social Capital Questionnaire [41]. The selected variables used to inform multiple imputation chained equations and to construct latent psychosocial profiles and demographic classes are presented in Table S1. Maternal psychological status during pregnancy was coded in a new variable derived from first- and second-trimester interviews, combining self-reported history of psychological disorders with confirmation of psychiatric diagnosis. Women who reported use of psychotropic medication during pregnancy were excluded from all analyses.

2.1.2. Child Cardiometabolic Risk Factors

At child follow-up visits, trained research assistants measured weight and height using validated scales (Seca Bellisima 841; Seca Corporation, Hanover, MD, USA) and stadiometers (Seca 213; Seca Corporation) according to standard operating procedures. We calculated BMI (weight/height^2) and categorised subjects into Normal, Overweight, or Obese using the International Obesity Task Force IOTF age- and sex-specific cut-offs [42]. Waist circumference (WC) was measured in duplicate to the nearest 0.1 cm in the standing position, at the high point of the iliac crest at the end of a gentle expiration, using a flexible tape measure (Seca 201). As bioelectric impedance analysis (BIA) was not available at the 4-year follow-up, we estimated child percentage body fat (%BF) using the Slaughter skinfold-thickness equation [43] using the mean of three consecutive measurements for triceps, subscapular, suprailiac, and quadriceps skinfold thicknesses, according to standardised techniques to the nearest 0.1 mm using a calibrated Harpenden caliper (Harpenden HSK-BI, CE-0120; Baty International, West Sussex, UK). At the 7- and 11-year follow-ups, body composition was measured using BIA by a tetra-polar device (Bodystat 1500; Bodystat Ltd., Douglas, UK). Paediatric specific BIA equation [44] was used to obtain %BF. Trained research assistants measured systolic (SBP) and diastolic (DBP) blood pressure levels on the child's right arm using an automatic oscillometric device (Dinamap, Pro Care 400; GE Medical Systems Ltd., Buckinghamshire, UK) with a cuff of appropriate size for arm circumference. The average of three measurements with 1 min intervals was used to calculate sex-, age- and height-percentiles [45]. Finally, non-fasting blood samples were collected from the children at the end of each visit, following standard procedures; samples were immediately spun, separated, and frozen at −80 °C. Analysis of lipids was performed by standard enzymatic methods (Medicon, Greece) on an automatic analyser (AU5400 high-volume chemistry analyser; Olympus America, Inc., Melville, NY, USA). These samples were used to assess the children's lipid profiles (total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides) as indicators of cardiometabolic health.

2.2. Study Sample

The analysis dataset was constructed by compiling data from different pregnancy follow-ups, as well as postnatal EPDS assessment, and includes 1483 mothers. Mothers under medication for psychological problems (N = 8) were excluded. Then, 135 cases with high missingness (>70%) were omitted, while ensuring that only fully uninformative cases were dropped. Multiple imputation was conducted on the full analytic sample (N = 1340). Psychometric profile analysis was restricted to participants with at least one observed psychometric indicator (N = 638), as cases with no observations did not provide sufficient anchor data for stable imputation of the psychosocial scales. The excluded cases had adequate demographic data (91.5% observed), and were retained in the demographic class analysis. Thus, the demographic class analysis used the larger sample because demographic information was available for participants who could not contribute to the psychosocial profile analysis.

Finally, the regression sample was restricted to mothers with both psychosocial profiles and demographic classes (N = 638), ensuring that the associations between these exposures and offspring outcomes were examined in a common analytic sample. Respective offspring cardiometabolic risk factors were available for 437 mother–child pairs at 4 years, 316 pairs at 7 years, and 198 pairs at 11 years of age. Baseline sociodemographic characteristics between families attending or not attending later follow-ups were compared using standardised mean differences (SMD), indicating differences in several characteristics, particularly maternal education, age, and origin, with differences becoming more pronounced at age 11.

2.3. Statistical Analysis

Descriptive analyses of the study population characteristics, exposures, and outcomes were conducted. Missing data varied across variables, with a higher proportion of missing observations for psychosocial indicators than for sociodemographic covariates. The magnitude of missingness and the patterns of co-occurring missing observations across the key variables included in the imputation model are presented in Supplementary Figure S1. Multiple imputation was applied on the full analytic sample (N = 1340) using MICE chained equations [46] with 50 iterations for 20 imputed datasets [47] under the Missing At Random (MAR) assumption. Functions PMM for continuous variables and logreg/polyreg for categorical variables were used. Categories with less than 20 observations were merged to prevent fragmentation of the sample.

Latent Profile Analysis (LPA), a branch of Gaussian finite mixture modelling, was used to identify underlying groups of mothers based on continuous indicator variables within each imputed dataset. The method uses a probabilistic model, which means that it models the probability of a study subject belonging to a distinct psychosocial profile [48]. Psychometric scales were standardised (*z*-scored) within each imputed dataset to a mean of 0 and standard deviation of 1, ensuring equal contribution of each indicator to the latent profile solution regardless of the original scale metric, as required by the Equal Variances/Equal Covariances (EEI) model structure which assumes equal variances across indicators. Latent profile models k = 1 to 5 number of distinct profiles were estimated across multiply imputed datasets on reduced sample N = 638 (≥1 psychosocial scale observed) to avoid classification based entirely on imputed data, as they provide no empirical information for class formation and rely entirely on MAR assumptions (Figure S2). In mixture modelling, where variance structure is critical, only individuals who contribute at least some real information to profile formation should be included [49].

Model fit was evaluated within each imputed dataset and the three-class solution was selected based on pooled Bayesian Information Criterion (BIC) and interpretability (Figure S3; mean BIC = −15,544, mean entropy = 0.789). To evaluate the appropriateness of the EEI covariance structure, EEI k = 3 and EVI k = 3 competing models were estimated and compared across all 20 imputed datasets. EEI exceeded EVI on BIC in 13 out of 20 imputations (mean ΔBIC = 6.9, range: −67.7 to 101.0). In the 14 imputations retained after label alignment (see below), EEI was selected in 13 of 14 (mean ΔBIC = −21.7), with mean class assignment agreement between structures of 86.7% (range: 68.5–94.7%) and profile means differing by an average of 0.25 SD (range: 0.11–0.54). The seven imputations showing lower EEI–EVI agreement largely overlapped with those independently identified as structurally inconsistent (5 out of 7), indicating that divergence between covariance structures reflected imputation-level instability rather than systematic model misspecification. Given that EEI was the better-fitting or equivalent model across stable imputations, and given its parsimony and established use in applied psychometric LPA, the EEI covariance structure was retained for all subsequent analyses. Label alignment was performed for the derived profiles via Euclidean distance on class centroids using imputation 20 as starting point. In progressive analyses, 14 imputed datasets were retained after the exclusion of six structurally inconsistent datasets with respect to the latent profiles. Imputations were excluded if the maximum Euclidean distance between their class mean profiles and the consensus reference exceeded 0.5 SD units. This post hoc criterion was based on a clear gap in the observed distance distribution: excluded imputations had distances >1.5, whereas retained imputations had distances <0.5, with none between these ranges, indicating a structural divergence rather than a minor sampling variation. Classification quality was acceptable across all three profiles and 14 imputations. Average posterior probabilities (AvePP) ranged from 0.871 to 0.893 across profiles and imputations, exceeding the recommended threshold of 0.70.

Odds of correct classification (OCC) ranged from 9.85 to 37.6, well above the threshold of >5 indicating adequate class separation [50]. A mean of 88.0% of participants showed posterior probabilities exceeding 0.70 for their assigned profile. Cross-imputation agreement was high (mean = 0.935), with 75.4% of participants receiving identical assignments across all imputations and 79.9% showing ≥90% consistency.

Demographic classes were obtained using latent class analysis (LCA) including twelve maternal and family characteristics: maternal age and origin, marital status, parental years in education and working status, number of older children, urban area of living, number of cars, and house ownership and size (m^2). Continuous variables (age, years in education, parity, house size) were recoded into ordinal levels. Function poLCA [51] in R version 4.5.2 was used to fit models for k = 1 to 5 classes (Figure S5). All 20 imputations converged to an equivalent three-class structure (N = 1340), with no structural instability identified across imputations. Label alignment across imputations was performed via Euclidean distance on item probability profiles, using imputation 1 as the reference.

Classification quality was considered acceptable, as AvePP ranged from 0.855 to 0.902 across classes and imputations (mean AvePP = C1: 0.855–0.897, C2: 0.863–0.902, C3: 0.858–0.895), exceeding the recommended threshold of 0.70, and OCC values ranged from 9.1 to 46.0 (OCC = C1: 9.8–38.4, C2: 9.8–46.0, C3: 9.1–45.4), well above the threshold of >5, indicating adequate class separation [50]. Mean entropy was 0.736 (range 0.719 to 0.757), exceeding the threshold of 0.70 and indicating acceptable separation between demographic classes. Modal assignment rate was 0.810. Cross-imputation classification consistency was high (mean agreement = 0.981), with 92.0% of participants receiving identical class assignments across all 20 imputations and 94.1% showing ≥90% consistency, exceeding the stability observed for the psychosocial profiles.

Multivariate linear regression models were used to examine associations of maternal psychosocial profiles (LPA classes) and demographic classes (LCA classes) with offspring continuous anthropometric and cardiometabolic outcomes, including weight, BMI, fat proportion, blood pressure, and lipid profiles at ages 4, 7, and 11 years. Effect estimates are presented as β coefficients with corresponding 95% confidence intervals (CI). Binary outcomes, including overweight/obese, waist circumference above 90th percentile, and hypertensive, were assessed using log-Poisson regression models with robust variances (the "sandwich" method) and effect estimates are presented as relative risk (RR) with corresponding 95% confidence intervals (CI). Child sex and exact age at assessment were included as covariates in all models.

Class assignments from LPA and LCA were used as predictors using the BCH correction method [52], which accounts for classification error in the posterior probability matrix. BCH-weighted regression models were fitted separately within each of the 14 retained imputed datasets, and effect estimates were pooled across imputations using Rubin's rules [53]. As a sensitivity analysis, regression models were repeated using modal class assignment with HC3 heteroscedasticity-robust standard errors [54] to assess the potential impact of classification error on parameter estimates [55].

All hypothesis testing assumes a 0.05 two-sided significance level. Stata S.E. version 13 (Stata Corp, College Station, TX, USA) was used for dataset preparation prior to analysis, whereas all analyses were performed using R version 4.5.2 with packages: mice (3.19.0), mclust (6.1.2), poLCA (1.6.0.2), and tidyverse (2.0.0).

3. Results

3.1. Baseline Characteristics

The final study sample, as presented in Table 1, consisted of 638 mother–child pairs. Mean maternal age at delivery was 29.7 years (SD = 5.0). The vast majority of mothers were

of Greek origin (94%) and had 12.8 years of education (SD = 2.9). Regarding employment status, over half of the women held a paid job (58.3%), while 23.2% were stay-at-home mothers, 14.8% were self-employed, and 3.6% worked as farmers or other. Most participants were married (89%), whereas in terms of parity, 43.4% had no other children, 37.7% had one older child, and 18.9% had two or more older children. The majority resided in urban areas (78%), while 22% lived in rural settings. Finally, most women lived in owned housing (72%), whereas 28% resided in rented homes.

Table 1. Maternal demographic characteristics (N = 638).

Characteristic	Mean (SD)/Median [IQR] or N (%)
Age at delivery	29.7 (5.0)/30.0 [26.0, 33.0]
Origin	
Non-Greek	41 (6.4%)
Greek	597 (93.6%)
Years in education	12.8 (2.9)/12.0 [12.0, 16.0]
Working status	
Stay at home	149 (23%)
Paid job	370 (58%)
Self-employed	96 (15%)
Farmer	13 (2.0%)
Other	10 (1.6%)
Marital status	
Married	567 (88.9%)
Engaged	60 (9.4%)
Other	11 (1.7%)
Number of other children	
None	276 (43.3%)
One	240 (37.6%)
Two or more	122 (19.1%)
Area of residence	
Urban	494 (77.4%)
Rural	144 (22.6%)
House tenure	
Owned	458 (71.8%)
Rented	180 (28.2%)

3.2. Child Cardiometabolic Outcomes

Of the 638 mothers, 337 (52.8%) gave birth to male and 301 (47.2%) to female children. The offspring cardiometabolic risk factors assessed at 4, 7, and 11 years of age, including weight, body mass index (BMI), cholesterol, triglycerides, systolic and diastolic blood pressure percentiles, fat proportion, and waist circumference, are shown in Table 2.

Table 2. Longitudinal offspring outcomes at 4, 7, and 11 years of age.

	4 Years		7 Years		11 Years	
Measure	**N**	**Mean (SD)** **Median [IQR]**	**N**	**Mean (SD)** **Median [IQR]**	**N**	**Mean (SD)** **Median [IQR]**
Age (years)	441	4.2 (0.2) 4.2 [4.1, 4.2]	318	6.6 (0.3) 6.5 [6.4, 6.7]	198	11.0 (0.3) 10.9 [10.8, 11.2]
Weight (Kg)	437	18.2 (3.0) 17.7 [16.3, 19.6]	316	24.7 (4.8) 23.8 [21.5, 27.4]	198	42.1 (9.6) 41.6 [35.3, 47.9]
BMI (Kg/m^2)	437	16.4 (1.9) 16.1 [15.3, 17.2]	316	16.9 (2.5) 16.4 [15.3, 18.2]	198	20.0 (3.5) 19.7 [17.5, 21.8]
Total cholesterol (mg/dL)	371	156.6 (29.4) 155.0 [139.0, 173.0]	298	162.2 (23.6) 162.0 [144.0, 176.0]	188	170.2 (30.5) 167.0 [150.5, 189.5]
Triglycerides (mg/dL)	371	70.9 (26.6) 67.0 [51.0, 84.0]	298	66.1 (31.9) 59.0 [45.0, 77.0]	188	88.4 (43.2) 75.0 [57.5, 107.0]
SBP percentile	349	43.1 (23.4) 39.8 [24.5, 60.1]	309	45.4 (24.7) 45.7 [24.7, 66.2]	198	51.2 (24.3) 51.1 [31.5, 69.7]
DBP percentile	349	57.4 (17.3) 57.6 [44.8, 70.1]	309	43.8 (19.1) 42.1 [29.4, 57.2]	198	46.6 (20.0) 43.6 [31.0, 60.8]
Fat proportion (%)	414	19.3 (5.8) 18.0 [15.3, 22.0]	313	24.3 (6.7) 23.6 [19.6, 28.5]	194	28.5 (8.9) 29.3 [21.3, 34.3]
Waist circumference (cm)	435	53.6 (4.8) 52.5 [50.5, 55.2]	316	58.8 (6.9) 56.9 [54.2, 62.2]	196	72.1 (10.1) 71.0 [64.6, 77.3]

BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

3.3. Maternal Psychosocial Profiles

Latent profile analysis identified three distinct maternal psychosocial profiles for the restricted study sample of 638 mothers (Figure 1). The distributions of the nine standardised scales, used for the construction of the profiles, are presented in Figure S4. The "Normative" profile comprised the largest proportion of the sample with a mean of 327 across imputations (51.2%, range 48.7% to 54.4%) and was characterised by scores close to the sample mean across all psychosocial indicators, with no marked elevations or reductions in any specific dimension. The "Resilient-Socially Resourced" profile comprised a mean of 183 (28.7%, range 25.2% to 34.0%) and was characterised by lower anxiety, neuroticism, and prenatal depressive symptoms, alongside higher extraversion, social engagement, and community integration, due to elevated perceptions of social value, participation, and safety. The "Psychosocially Vulnerable" profile comprised a mean of 128 (20.1%, range 17.2% to 21.6%) and was characterised by higher anxiety, neuroticism, and prenatal depressive symptoms, alongside lower extraversion, and markedly lower social connectedness.

3.4. Latent Socioeconomic Classes

Latent class analysis resulted in three discrete maternal demographic classes (N = 1340). A three-class solution (k = 3) revealed distinctive sociodemographic profiles primarily differentiated by parental education, housing conditions, asset ownership, and family structure (Figure 2). Class 1 (45.9%), the largest group, reflects the highest SES profile. It is distinguished by high parental education (66.6% of mothers and 51.3% of fathers with tertiary education), greater asset ownership (59.1% owning two cars), and relatively larger or mid-sized housing. These households are predominantly urban, have fewer children, and exhibit strong labor market participation, especially among mothers (paid and self-employed). Home ownership is also high (71.2%). This class corresponds to higher-SES urban professional families with dual-income characteristics and greater material resources.

Class 2 (38.1%) represents a more traditional and moderately resourced profile. While parental education is mainly at the middle level, this class shows the highest likelihood of rural residence (40.5%), home ownership (92.7%), and larger family size (32.5% with two or more children). Occupational patterns indicate higher levels of self-employment and farming, particularly among fathers. Nearly all members are of Greek origin. This class can be interpreted as middle-SES, rural, and traditionally structured households with stable living conditions. Class 3 (16.0%) was characterised by comparatively lower socioeconomic status (SES), with high probabilities of low parental education (especially fathers: 63.4% compulsory), residence in small dwellings (82.2% in the lowest house-size tertile), and renting (89.2%). Asset ownership is limited (predominantly one car), and this class has the highest proportion of non-Greek origin (42.1%). These households are predominantly urban and exhibit moderate maternal employment.

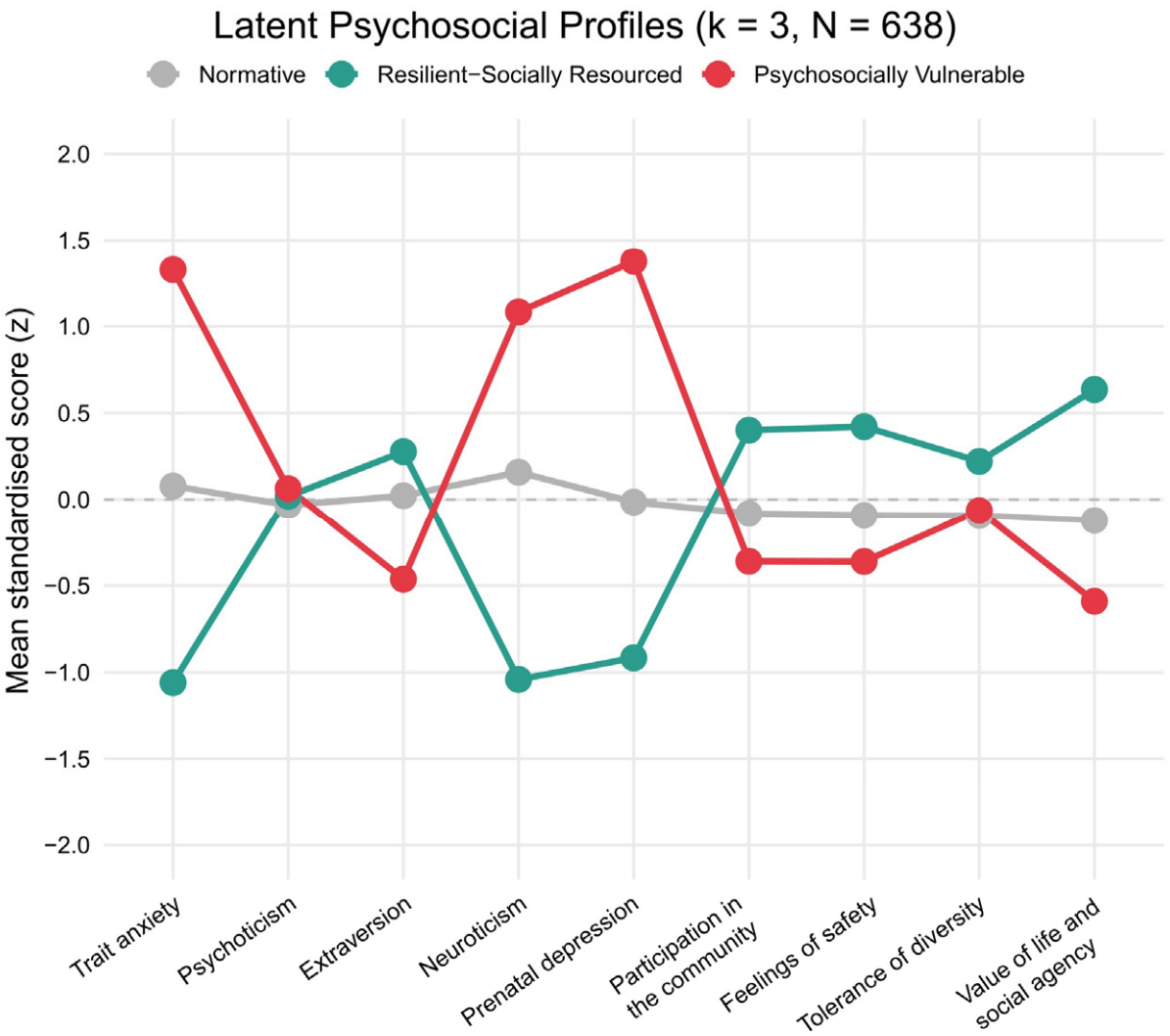


Figure 1. Mean standardised scores of perinatal psychosocial scales by LPA derived maternal latent profiles (N = 638).

Overall, this class reflects lower-SES urban renting families with more diverse backgrounds. Taken together, the latent classes form a clear SES gradient ranging from urban renters (Class 3), to traditional rural households (Class 2), to urban professional families (Class 1). Item response probabilities for all classes are presented in Table S2.

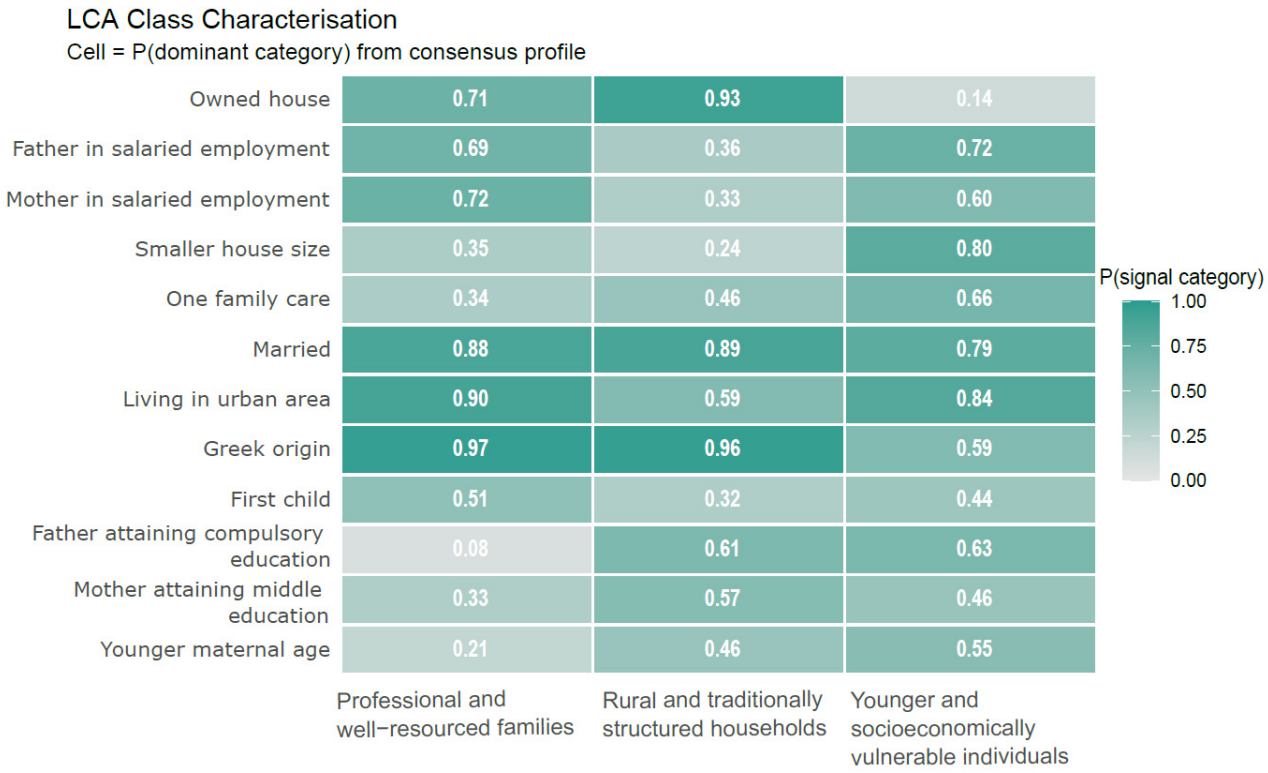


Figure 2. Heatmap with probabilities of dominant categories of latent socioeconomic classes (N = 1340).

3.5. Exploratory Associations with Child Cardiometabolic Health

Following the derivation of maternal psychosocial profiles (LPA) and demographic classes (LCA), linear regression models were fitted to examine their associations with offspring anthropometric and cardiometabolic outcomes from birth to pre-adolescence. Each outcome was assessed at ages 4, 7, and 11 years and was modelled separately, with maternal psychosocial profile and demographic class entered simultaneously as predictors. Child sex and exact age at assessment were included as covariates in all models. BCH-corrected estimates were pooled across the 14 retained imputed datasets using Rubin's rules. Results are presented in Figure 3 as β coefficients with 95% confidence intervals.

The "Normative" psychosocial profile and the "Professional, well-resourced families" demographic class were set as the reference categories. Across the three assessment ages, estimates for offspring weight, BMI, fat proportion, and waist circumference showed no clear evidence of consistent associations with maternal psychosocial profiles or demographic classes. Estimates for LDL cholesterol were positive among children from "Rural, traditionally structured households" across the three ages, although the corresponding confidence intervals included the null. For triglycerides, the estimated difference between children of mothers with the "Psychosocially Vulnerable" profile and those with the "Normative" profile was −10.34 (95% CI: −18.62 to −2.06) at age 4; estimates at ages 7 and 11 were also negative, although less precise. At age 4, the estimated difference in SBP percentile between children of mothers with the "Resilient-Socially Resourced" profile and those with the "Normative" profile was 8.45 (95% CI: 2.29 to 14.61). No consistent pattern of associations was evident for DBP percentile.

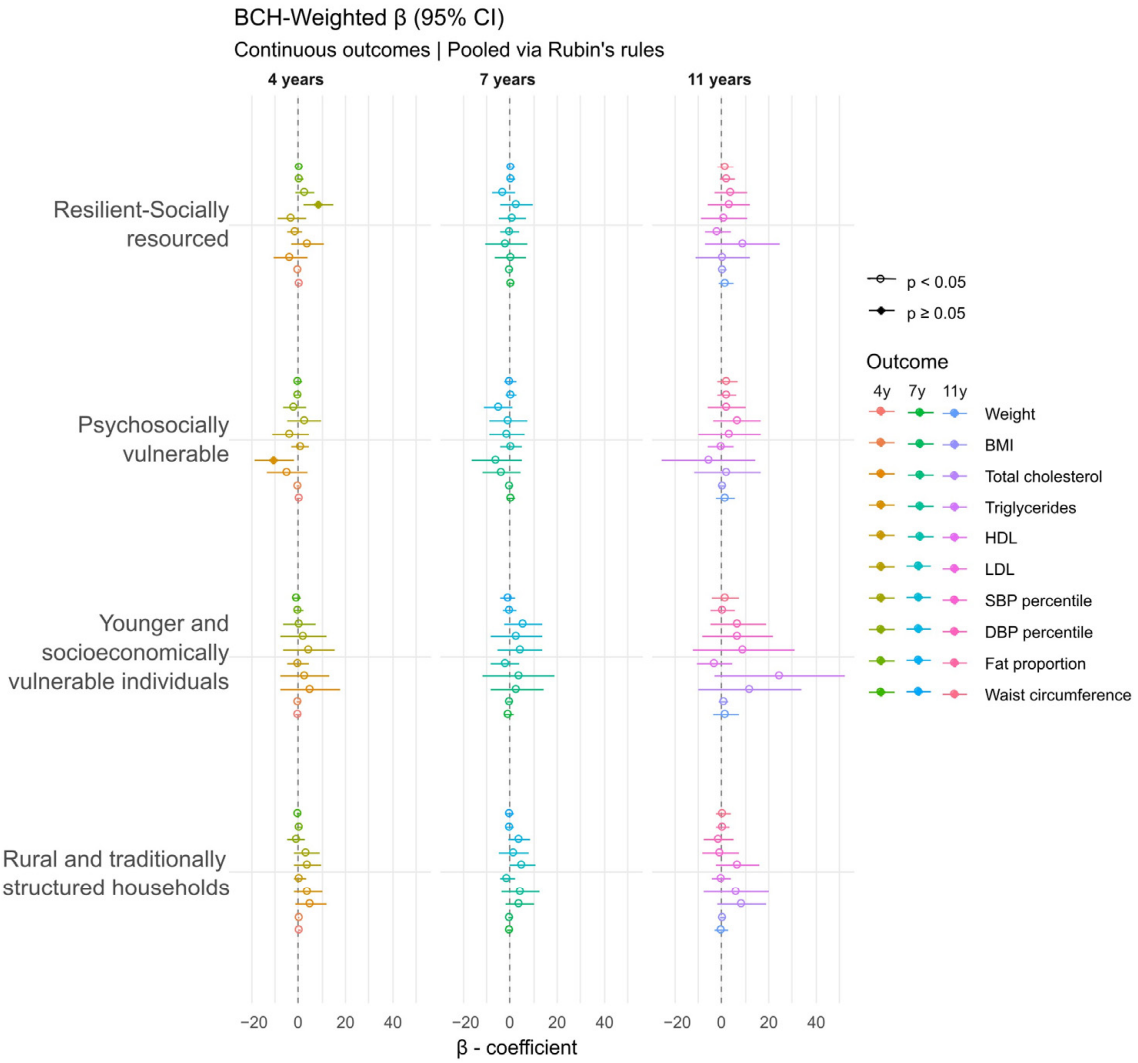


Figure 3. Linear regression estimates of effect for maternal psychosocial profiles and demographic classes on continuous offspring cardiometabolic risk factors at 4, 7, and 11 years of age. B-coefficients and corresponding 95% confidence intervals obtained from linear regression models, adjusted for child sex and exact age at measurement. Reference category: "Normative" for psychosocial profiles and "Professional, well-resourced families" for demographic classes. BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

Relative risk estimates from log-Poisson regression models with robust SEs for binary offspring cardiometabolic risk factors are presented in Figure 4. At age 4, the estimated relative risk of obesity among children from "Rural, traditionally structured households" was 2.62 (95% CI: 1.17 to 5.85) compared with children from "Professional, well-resourced families". The estimated relative risk of hypertension among children from "Younger and socioeconomically vulnerable individuals" was 3.17 (95% CI: 1.09 to 9.26) relative to the same reference class. Both estimates were imprecise, as reflected in their wide confidence intervals, and should be interpreted cautiously in view of the exploratory nature of the analyses.

At a final step, sensitivity analysis was performed to compare the obtained results from the BCH correction of the estimated standard errors (SE) with those without the correction. As shown in Figure S6, no alterations were observed on the size or in the statistical significance of effect estimates.

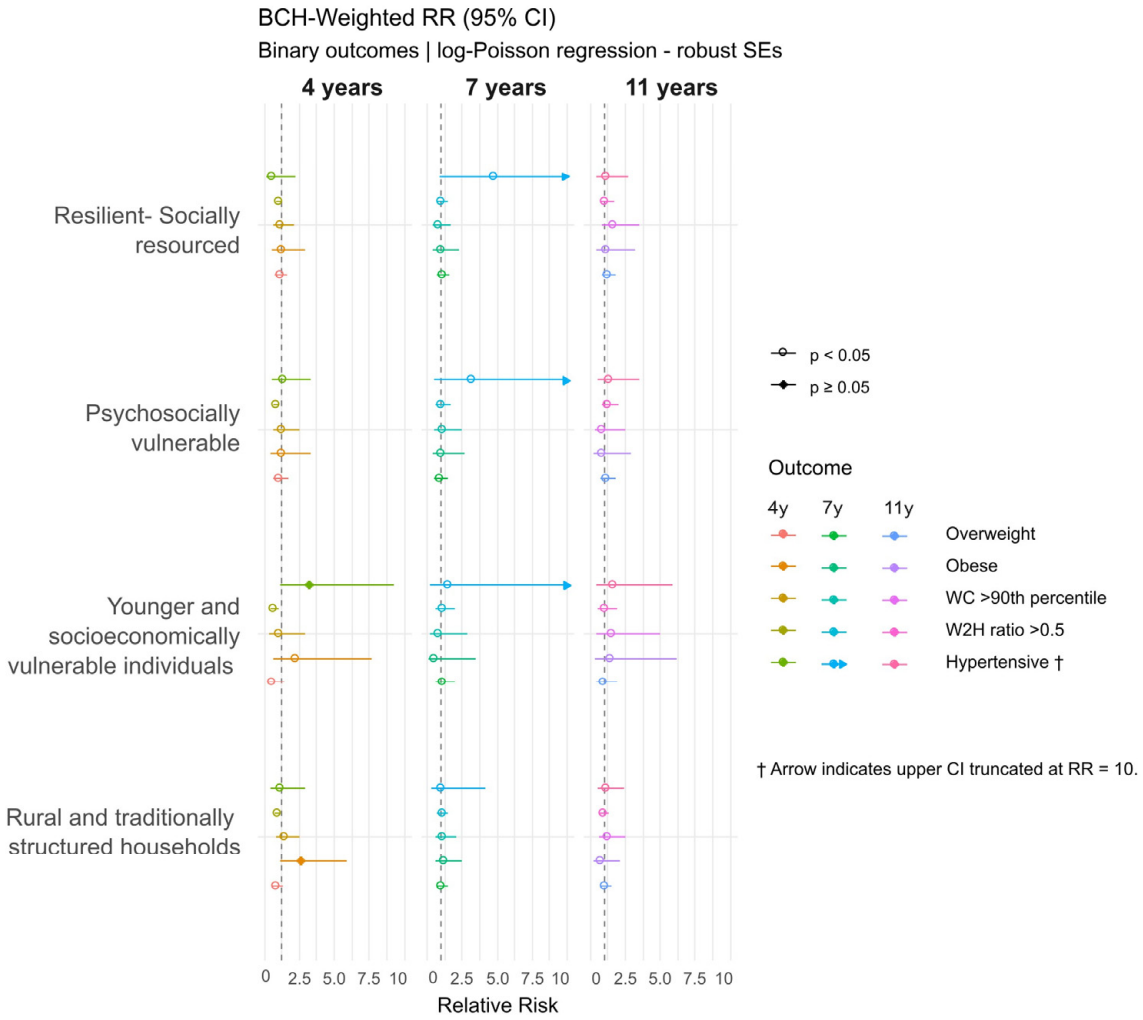


Figure 4. Coefficient plot of the effect estimates for maternal psychosocial profile and demographic class on binary offspring cardiometabolic risk factors at 4, 7, and 11 years of age. Relative risk and corresponding 95% confidence intervals obtained from log-Poison with robust variances regression models, adjusted for child sex and exact age at measurement. Reference category: "Normative" for psychosocial profiles and "Professional, well-resourced families" for demographic classes. BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

4. Discussion

The present study aimed primarily to identify maternal psychosocial profiles during pregnancy using a person-centred approach to examine the co-occurrence of personality traits, anxiety, depression, and social capital. Three distinct and theoretically coherent profiles emerged: a "Normative" profile, a "Resilient–Socially Resourced" profile characterised by psychological well-being and high social capital, and a "Psychosocially Vulnerable" profile characterised by elevated distress and reduced social connections.

Notably, the latent profiles identified in this study reflect the tendency for psychosocial characteristics to cluster within individuals. The "Psychosocially Vulnerable" profile combined elevated anxiety, depressive symptoms, and neuroticism with low social capital, whereas the Resilient–Socially Resourced profile combined favourable psychological functioning with high social engagement and community integration, alongside elevated perceptions of social value, participation, and safety. This pattern is consistent with previous research suggesting that psychological distress and social resources are highly interrelated rather than independent concepts [34]. Consequently, the person-centred approach adopted in this study may provide a more comprehensive representation of maternal psychosocial

functioning than traditional variable-centred analyses that examine individual psychosocial exposures separately [56]. The identified profiles support abstracting maternal psychosocial functioning as a multidimensional construct incorporating interrelated psychological and social characteristics.

Maternal psychological distress during pregnancy has been proposed as a developmental programming exposure within the DOHaD framework, although epidemiological evidence regarding offspring cardiometabolic outcomes remains inconsistent [16]. To address our secondary objective, we investigated associations between maternal psychosocial and family socioeconomic and demographic characteristics and child cardiometabolic outcomes. Despite capturing meaningful heterogeneity in maternal psychosocial functioning and family socioeconomic classes, the associations with offspring cardiometabolic outcomes from 4 to 11 years of age were limited and inconsistent. Several explanations may account for this pattern, including the influence of postnatal environmental factors, the relatively low levels of psychological distress in this population, and the possibility that associations operate indirectly through behavioural and environmental pathways. The isolated associations observed at age 4 should be interpreted cautiously in light of the exploratory nature of the analyses and the large number of outcomes, time points, and comparisons examined. The lower triglyceride concentrations among children of mothers in the "Psychosocially Vulnerable" profile and the higher systolic blood pressure percentile among children of mothers in the "Resilient–Socially Resourced" profile were not consistently observed at ages 7 and 11. These findings may therefore reflect chance arising from multiple comparisons rather than robust associations and require replication in independent studies. The declining sample size across follow-up assessments, particularly at age 11, may also have reduced the precision of the estimates and limited the ability to detect associations at later ages.

The influence of maternal psychosocial characteristics during pregnancy may have been attenuated by postnatal environmental factors that increasingly shape child growth and metabolic health over time. Evidence suggests that childhood adiposity is shaped by complex, cumulative, and developmentally dynamic processes rather than direct prenatal psychosocial influences [57]. Maternal psychosocial stress has been more consistently linked to offspring behavioural pathways such as lower physical activity and higher sedentary behaviour, while associations with dietary intake are mixed, suggesting that effects on energy balance are likely indirect [58]. While prenatal exposures are central to developmental programming models, children's health trajectories are also influenced by a range of postnatal determinants, including dietary patterns, physical activity, sleep behaviours, parenting practices, family functioning, and broader socioeconomic circumstances that may buffer or amplify the effects of prenatal psychosocial exposures. Furthermore, psychosocial characteristics were assessed during pregnancy and may not reflect maternal psychological functioning throughout the postnatal period. Changes in maternal mental health, family circumstances, and social support after birth may modify associations between prenatal psychosocial profiles and subsequent child health. Alternatively, associations may become more apparent at later developmental stages, although longer follow-up is needed to investigate this possibility.

Some studies have reported associations with altered growth trajectories and increased adiposity or obesity risk later in childhood and adulthood [17,20], while others have observed no associations with childhood BMI or overweight status [19,59]. Our findings are more consistent with the latter studies and may reflect limited exposure contrast in general population samples, where levels of psychological stress may be predominantly mild to moderate. Although the "Psychosocially Vulnerable" profile was characterised by elevated anxiety, depression, and neuroticism relative to the other profiles, the observed variation may have reflected differences in psychological functioning rather than severe or chronic

psychopathology. This limited exposure contrast may partly explain the weak associations observed in this sample.

Early-life social disadvantage and adverse childhood experiences have been associated with obesity risk through behavioural mechanisms such as emotional overeating, highlighting the role of upstream social determinants in shaping self-regulatory eating behaviours [60]. BMI development follows heterogeneous and non-linear trajectories, with early divergence driven by interacting biological and environmental factors [61]. Taken together, these findings are consistent with the possibility that pathways to childhood obesity are indirect and cumulative and may not be captured by prenatal psychosocial profiles alone. Evidence from large population-based cohorts further suggests that associations may vary according to developmental stage and child sex, highlighting the complexity of these relationships [62,63].

Evidence concerning associations between prenatal psychosocial exposures and offspring lipid metabolism remains limited, while findings relating prenatal psychological distress to offspring blood pressure or vascular function are also inconsistent [16,62,63]. Consequently, the isolated associations observed at age 4 in the present study should not be interpreted as evidence of established biological effects. The duration of follow-up may have been insufficient to detect the full consequences of prenatal psychosocial exposures. Developmental programming effects may not become fully apparent until adolescence or adulthood, when metabolic regulatory systems are challenged by pubertal changes, increasing adiposity, or adverse lifestyle factors. Several cardiometabolic risk markers, including insulin resistance, dyslipidaemia, and hypertension, often emerge more clearly later in the life course. Longer follow-up may therefore help determine whether associations emerge or become more apparent during adolescence or adulthood, although this possibility remains to be established.

Finally, household socioeconomic and demographic context showed some associations with offspring cardiometabolic outcomes. Children from "Rural, traditionally structured households" had a higher estimated relative risk of obesity, while children of "Younger and socioeconomically vulnerable individuals" were more likely to have an estimated higher relative risk of hypertension at the age of 4 years. However, these estimates, particularly that for hypertension, had wide confidence intervals, indicating considerable uncertainty regarding the magnitude of the associations. Given the exploratory nature of the analyses, these findings should be interpreted cautiously and require confirmation in further studies. Nevertheless, they may suggest that broader social and material conditions contribute to childhood cardiometabolic health, although the present findings do not establish a consistent pattern of associations across outcomes and follow-up ages. This interpretation is consistent with ecological models of health and emerging DOHaD perspectives emphasising the cumulative effects of social and environmental adversity across development.

An important strength of this study is the holistic conceptualisation of maternal psychosocial health. By employing latent profile analysis, a person-centred analytical approach, the study captured naturally occurring combinations of personality traits, psychological distress, and social capital. This approach acknowledges that these factors reflect interrelated characteristics which jointly can influence maternal well-being [34]. Additional analytic tools, such as the application of multiple imputation and BCH correction methods, enhance robustness. Excluding structurally divergent imputations was a conservative approach to preserve model stability and interpretability, as these imputations showed weaker class separation, lacked an identifiable high-distress class, and yielded different latent structures, undermining the uniformity of estimands required for valid pooling under Rubin's rules.

A further strength is the longitudinal follow-up of a well-established mother–child cohort, which provides an appropriate framework for investigating the Developmental

Origins of Health and Disease; early-life exposures are understood to shape long-term physiological functioning through processes of developmental programming [64]. While this framework has historically emphasised adverse exposures such as undernutrition or maternal metabolic dysregulation, the present findings emphasise the importance of considering psychosocial environments as complex contextual influences that may interact with other developmental exposures. Pregnancy and child cohort studies offer a unique platform to study a wide range of early-life stressors linked with individual biological, developmental, and health trajectory variations, and with the onset of non-communicable diseases [65]. Secondary analysis of data related to social, psychological, and lifestyle determinants can capitalise on these setups by performing hypothesis-driven research on early-life stressors influencing growth and cardiometabolic health trajectories across the life course [66,67].

However, limitations must also be acknowledged. Firstly, psychosocial characteristics were assessed during pregnancy and may not fully capture changes in maternal psychological functioning across the prenatal and postnatal periods. Residual confounding by unmeasured factors, such as maternal diet, genetic influences, and detailed postnatal environmental exposures, cannot be excluded. Attrition across follow-up assessments may have introduced selection bias and reduced the precision and generalisability of the findings, particularly at age 11. Participants with observed follow-up measurements differed from those without measurements on several baseline characteristics, suggesting that follow-up availability may be associated with sociodemographic characteristics. Therefore, selection bias cannot be ruled and should be considered when interpreting the results. Additionally, psychosocial measures were based on self-report, which may introduce measurement bias. The relatively small size of some latent profiles may have limited statistical power, and the absence of biological markers precludes direct examination of underlying mechanisms. Given the number of statistical tests conducted, isolated significant findings should be interpreted cautiously. The reduced sample size at later follow-up, particularly at 11 years, limited our ability to investigate potential interactions between psychosocial profiles and socioeconomic context, despite evidence that developmental programming effects may emerge under cumulative or interacting exposures. Furthermore, although the three-profile solution was selected based on the model-selection criteria and the interpretability of the identified profiles, the profile structure was not independently validated. Therefore, the reproducibility and generalisability of the identified profiles to other populations remain uncertain, and replication in independent cohorts is warranted.

These findings contribute to the literature on maternal mental health and offspring cardiometabolic development, while highlighting the heterogeneity and inconsistency of observed associations. The results do not support a straightforward model in which maternal prenatal psychosocial profiles consistently predict offspring cardiometabolic outcomes. Instead, they highlight the potential value of person-centred approaches, such as latent profile analysis, for characterising the co-occurrence of psychological and social factors beyond traditional single-exposure frameworks. Future research should therefore move towards integrative, multi-level designs that combine psychosocial, behavioural, and biological data to better elucidate potential mechanisms linking maternal mental health with offspring metabolic regulation. Longitudinal studies extending into adolescence and adulthood are also needed to assess whether associations emerge, strengthen, or attenuate over time, and to differentiate between transient growth variation and persistent cardiometabolic risk trajectories. Finally, future work should include maternal and paternal psychosocial factors within broader socioeconomic and environmental contexts, in order to better understand how multiple layers of early-life exposure jointly shape cardiometabolic development and to avoid overly reductionist interpretations of psychosocial risk.

5. Conclusions

Overall, this study demonstrates that distinct maternal psychosocial profiles during pregnancy, capturing variation in personality traits, anxiety, depressive symptoms, and social capital, can be robustly identified in a population-based cohort. Maternal psychosocial profiles showed limited and largely age-specific associations with offspring anthropometric and cardiometabolic outcomes during childhood. These findings should be interpreted as exploratory, as the observed associations were not consistent across outcomes and follow-up ages and do not establish a consistent effect of maternal psychosocial profiles on cardiometabolic development throughout childhood. The declining sample size at subsequent follow-up assessments, particularly at age 11, further limits the precision of the estimates and the ability to draw firm conclusions about the persistence of these associations. Although the possibility that associations may emerge at later developmental stages, including adolescence or early adulthood, cannot be excluded, this requires investigation in studies with longer follow-up. Our findings align with a growing body of evidence suggesting that associations between prenatal maternal psychological distress and offspring cardiometabolic and vascular outcomes are heterogeneous and often weak, with large cohort studies failing to demonstrate robust links with childhood blood pressure, vascular function, or adiposity after accounting for confounding factors. Taken together, the results provide preliminary evidence on the relationship between maternal psychosocial profiles and offspring cardiometabolic outcomes. Further studies involving larger samples, longer follow-up, and repeated assessments across developmental stages are needed to clarify whether these associations persist, emerge later, or vary over time.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/epidemiologia7060157/s1, Table S1: Selected variables from Rhea cohort data repository; Figure S1: (A) Proportion and pattern, and (B) Intersection plot of missing values for key variables used for constructing the maternal psychosocial profiles and demographic classes; Figure S2: Convergence of psychosocial scales in 20 imputed datasets; Figure S3: Pooled BIC for latent profile analysis with k = 1 to 5 profiles across 20 imputed datasets (N = 638); Figure S4: Distribution of the nine standardised scales used in latent profile analysis by profile (N = 638); Figure S5: Pooled BIC for latent class analysis with k = 1 to 5 profiles across 20 imputed datasets (N = 1340); Table S2: Item probability profiles for each class derived from latent cluster analysis (N = 1340); Figure S6: Sensitivity analysis comparing significance of effect estimates with and without BCH correction of the estimated SEs.

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Informed Consent Statement: Written, informed consent was provided by all participants after complete description of the study at all phases and permission was granted to use these data in future analyses within the Rhea birth cohort study framework.

Data Availability Statement: The dataset analysed in this study contains clinical and physiological information of pregnant women and their children and cannot be shared publicly due to ethical and legal restrictions imposed by the University General Hospital of Heraklion and the University of Crete Research Ethics Committees. Researchers may request access to the full anonymised dataset by contacting the corresponding authors, subject to approval by the study steering committee and completion of a data use agreement.

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Conflicts of Interest: The authors have nothing to declare.

Abbreviations

The following abbreviations are used in this manuscript:

AvePP	Average posterior probability
BIA	Bioelectric impedance analysis
BIC	Bayesian Information Criterion
BMI	Body Mass Index
CI	Confidence intervals
DBP	Diastolic blood pressure
DOHaD	Developmental Origins of Health and Disease
EEI	Equal Variances/Equal Covariances model
EPDS	Edinburgh Postnatal Depression Scale
EPQ	Eysenck's Personality Questionnaire
HPA	Hypothalamic–pituitary–adrenal
IOTF	International Obesity Task Force
LCA	Latent class analysis
LPA	Latent Profile Analysis
MAR	Missing at random assumptions
MICE	Multiple imputation chained equations
OCC	Odds of correct classification
RR	Relative risk
SBP	Systolic blood pressure
SD	Standard deviation
STAI	State-Trait Anxiety Inventory
WC	Waist circumference
%BF	Percentage body fat

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