Pathological and non-pathological variants of restrictive eating behaviors in middle childhood: A latent class analysis

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Although the exact nature and classificatory boundaries of restrictive eating behaviors are vague, a central theoretical definitional feature for delineation may be the presence of weight and shape concerns that may motivate children to restrict their eating behavior and dietary variety. Unlike those who fear to gain weight and intentionally restrict their food intake accordingly, which might be indicative for clinically significant psychopathology, avoidant and restrictive eating behaviors due to reasons other than weight and shape concerns may not coercively be associated with psychopathology, for example, picky eating or food neophobia in early childhood (Dovey, Staples, Gibson, & Halford, 2008). However, the theoretical separation of these restrictive eating behaviors from body image disturbances warrants investigation, especially in middle childhood, when early-onset restrictive eating behaviors still continue (Taylor, Wernimont, Northstone, & Emmett, 2015) and body image disturbances typically emerge (Calzo et al., 2012).

Indeed, restrictive eating behaviors in early childhood are very common and associated with varying degrees of stability and clinical significance (Bryant-Waugh, Markham, Kreipe, & Walsh, 2010; Taylor et al., 2015). Most research into early-onset restrictive eating disturbances has focused on picky eating, characterized by low food enjoyment, slowness in eating, and avoidant or highly selective eating behaviors (Jacobi, Schmitz, & Aras, 2008; Mascola, Bryson, Agras, 2010), although a clear definition is still lacking (Cardona Cano, Hoek, & Bryant-Waugh, 2016). Most variants of picky eating are deemed to be developmentally appropriate eating behaviors in children up to six years with high prevalence and high remission rates (e.g., Taylor et al., 2015; Cardona Cado et al., 2016); however, there is a paucity of studies on picky eating in older children (Jacobi et al., 2008; Mascola et al., 2010; Xue et al., 2015). In addition, due to the scarcity of evidence, it is not clear currently whether children who eat selectively show psychosocial impairments, increased eating disorder psychopathology, or underweight problems (Cole, An, Lee, & Donovan, 2017; Equit et al., 2013; Jacobi et al., 2008; Machado, Dias, Lima, Campos, & Gonçalves, 2016; Micali et al., 2011; Taylor et al., 2015; Van Tine, McNicholas, Safer, & Agras, 2017). However, there is evidence indicating that picky eating is associated with parental burden (Mascola et al., 2010; Micali et al., 2011) and specific parental feeding practices such as pressuring the child to eat (Tharner et al., 2014; Antoniou et al., 2016).

Strikingly, little research focused on assessing other variants of previously described restrictive eating behaviors for reasons other than weight control (Bryant-Waugh et al., 2010), such as food restriction due to emotional problems or eating-related anxiety, although these motivations may be prominent features for inadequate food intake, particularly in treatment-seeking children (Bryant-Waugh et al., 2010). Importantly, only some variants of early-onset restrictive eating behaviors are related to physical, developmental, or psychosocial impairment and are considered as a feeding or eating disorder within the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2013). Recently introduced in the DSM-5, avoidant/restrictive food intake disorder (ARFID; APA, 2013) is characterized by the persistent failure to meet appropriate nutritional or energy needs (APA, 2013), based on a range of different motivations, such as a lack of interest in eating, sensory sensitivities to food, food- or eating-related anxiety, or emotional problems (APA, 2013; Bryant-Waugh & Lask, 1995). Unlike children with anorexia nervosa (AN; APA, 2013), those with ARFID lack excessive concern about weight and shape or drive for thinness. Evidence from clinical samples presenting for eating disorder treatment indicated substantial prevalence rates of ARFID (up to 22.5%; Fisher et al., 2014; Nicely, Lane-Loney, Masciulli, Hollenbeak, & Ornstein, 2014; Ornstein et al., 2013) and associations with male sex, low body weight (Fisher et al., 2014; Nicely et al., 2014), and a high comorbidity with anxiety disorders (Fisher et al., 2014; Nicely et al., 2014) and medical conditions (Fisher et al., 2014). However, the nature of ARFID remains poorly understood, especially in non-clinical populations (Eddy et al., 2014; Kurz, Van Dyck, Dremmel, Munsch, & Hilbert, 2015, 2016). The only community-based study revealed that 3.2% of Swiss school children aged 8-13 years, particularly those with lower weight status, reported key symptoms of ARFID at least often based on the Eating Disorders in Youth-Questionnaire (EDY-Q; Van Dyck & Hilbert, 2016; Kurz et al., 2015, 2016); a standardized, interview-based assessment of ARFID is still lacking.

Latent Class Analysis (LCA) is an empirical technique for identifying latent subgroups of individuals on the basis of observed variables (Lazarsfeld & Henry, 1968). Within the last years, LCA has become an important approach in eating disorder research, for example, for identifying eating disorder phenotypes in children and adolescents from the community (Micali et al., 2017; Swanson et al., 2014). Within a clinical sample of 5-12 year old children with restrictive eating disorders, Pinhas et al. (2016) revealed two clusters with similarly high levels of food avoidance, but distinct patterns of weight and shape concern and over exercising, based on LCA. While the first cluster resembled an AN phenotype, patients of the second cluster showed symptoms congruent with ARFID. However, virtually nothing is known about whether this finding can be transferred to population-based samples which would be valuable for elucidating the heterogeneity and pathology of restrictive eating behaviors under consideration of body image disturbances in the community.

In this regard, Equit et al. (2013) provided first evidence in 4-7 year old children from the community by examining the latent structure of 13 problematic eating behaviors, such as picky eating, eating-related anxiety, or binge eating. While 61% of children were categorized as normal eaters, 34% were restrictive eaters mainly characterized by picky eating, and 5%, mostly girls, were labeled as weight worriers because they presented with some restrictive eating behaviors in combination with feelings of fatness and actual overweight (Equit et al., 2013). Although the study indicated that a substantial proportion of children were characterized by restrictive eating behaviors, there is debate about whether the identified clusters may be found in older children and adolescents. In addition, cluster validation analyses were limited to few variables on children's eating behavior and socio-demographics; body image disturbances were not systematically examined (Equit et al., 2013). Thus, it remains unclear whether the clusters differed in clinically relevant variables, such as general and eating disorder psychopathology, and the presence of ARFID symptoms.

In conclusion, in contrast to developmentally normative restrictive eating behaviors in early childhood which are evolutionarily grounded or related to infant sensory defensiveness (Cardona-Cado et al., 2016; Dovey et al., 2008), virtually nothing is known about the prevalence and clinical significance of early-onset restrictive eating behaviors in older children (Taylor et al., 2015) and to which extent these eating behaviors are related to body image disturbances as children grow older, which would allow for a more precise description of restrictive eating behaviors across child age ranges and help to evaluate specific targets for intervention. Thus, in an attempt to empirically delineate the heterogeneity of restrictive eating profiles in children across age ranges, the present study aimed at subtyping children based on their self-reported restrictive eating behaviors and shape concern in 7-14 year old children from the German general population. We hypothesized to identify subtypes characterized by restrictive eating behaviors with and without shape concern as well as children without restrictive eating patterns and functional body image. For cluster validation, socio-demographic data, objective anthropometric measures and a range of clinical variables including eating disorder and general psychopathology, the presence of ARFID symptoms and parental feeding practices were compared across identified subgroups.

Methods

Procedure

Data of the present study were derived from the ‘Leipzig Research Centre for Civilization Diseases (LIFE)’ Child study, a large prospective population-based cohort study which aims to identify risk factors of childhood obesity and its comorbidities. Inclusion in the LIFE Child study requires all children and adolescents to live in the area of Leipzig, to have sufficient German language skills, and being able to participate in at least one on-site assessment day. Study participants are recruited via advertisement at different institutions such as university hospitals, local clinics, public health centers, schools, and partner study centers. For a detailed description of the design and procedures of the LIFE study see Poulain et al. (2017) and Quante et al. (2012). Until January 2017, *N* = 846 7-14 year old children completed the EDY-Q (Van Dyck & Hilbert, 2016), assessing diverse restrictive eating behaviors in children. All participants with at least one missing value (*n* = 36, 4.3%) and/or invalid responses (*n* = 11, 1.3%) were excluded from the analyses resulting in a final sample of *N* = 799 participants.

All parents provided informed consent. Written assent was also obtained from the children if they were ≥ 12 years of age. The Ethics Committee of the Medical Faculty of the University of Leipzig, Germany, approved the methodological concept for the conduct of the LIFE study including the consent procedure (Reg. No. 264-10-19042010).

Participants

The final child sample consisted of *N* = 799 children (*n* = 431 girls, 53.9%) between the ages of 7 and 14 years (*M* = 10.50 years, *SD* = 2.02 years). Mothers’ mean age was 40.8 years (*SD* = 5.3 years) and their mean body mass index (BMI; kg/m^2) was 25.5 (*SD* = 5.5). For those providing data on family status (*n* = 520) and nationality (*n* = 658), the majority of mothers was partnered (*n* = 400, 76.9%) and of German nationality (*n* = 653, 99.2%). To assess the families' socio-economic status a modified Winkler Index was used which summarizes information about mothers' or fathers' highest educational degree, professional degree, current profession, and household net income (Lange et al., 2007). Overall, families had a medium socio-economic status based on the modified Winkler index with *M* = 13.42 (*SD* = 3.45), ranging from 3 to 21 with higher values indicating higher socio-economic status. Categorially, *n* = 65 (8.4%) families were classified as having low socio-economic status, *n* = 345 (44.5%) as medium socio-economic status, and *n* = 365 (47.1%) as high socio-economic status.

BMI for children was calculated from objectively measured weight and height. Children's BMI was transformed into BMI standard deviation scores (BMI-SDS) using age- and sex-specific reference data collected in Germany (Kromeyer-Hauschild et al., 2001). The 3^{rd}, 10^{th}, 90^{th}, and 97^{th} BMI percentile were used to determine severe underweight, underweight, overweight, and obesity, respectively. For children, the mean BMI-SDS was 0.14 (*SD* = 1.13, range -3.23 – 3.47), with *n* = 13 (1.6%) children having severe underweight, *n* = 54 (6.8%) underweight, *n* = 595 (74.4%) normal weight, *n* = 58 (7.4%) overweight, and *n* = 79 (9.9%) obesity.

=== Please insert Table 1 ===

Measures

Eating Disorders in Youth-Questionnaire (EDY-Q). The EDY-Q (Van Dyck & Hilbert, 2016) is a brief screening instrument for assessing early-onset restrictive eating disturbances in 8-13 year old children by self-report. Among the 14 items in total, 12 items capture general food avoidance, disinterest in eating, emotional food avoidance, picky eating, food neophobia, fear of choking, fear of swallowing, sensory food avoidance, underweight problems (two items), and body image disturbances (two items). Two additional EDY-Q items briefly address pica and rumination disorder, two other early-onset feeding or eating disorders described in the DSM-5 (APA, 2013); however, these items were not included in the present analysis as the focus of the study was on restrictive eating disturbances. The items were developed based on DSM-5 criteria for ARFID (APA, 2013), the Great Ormond Street criteria (Bryant-Waugh & Lask, 1995), and available literature on early-onset restrictive eating disturbances (e.g., Bryant-Waugh et al., 2010). All items were rated on a 7-point Likert scale ranging from 0 = *never* to 6 = *always.* Psychometric analyses showed adequate discriminant, divergent, and convergent validity of EDY-Q items, as well as moderate internal consistency for the EDY-Q mean score (in this study $\alpha = .55$; Kurz et al., 2015, 2016), justifying further item level analyses.

For determining the presence of ARFID symptoms, children were required to report the following symptoms at least often (≥ 4) as reported by Kurz et al. (2015): disinterest in food, sensory food avoidance, fear of choking, and underweight problems, while distorted cognitions about weight and shape had to be reported less than sometimes (< 3). In addition to the three restrictive eating behaviors, the remaining EDY-Q items on general and emotional food avoidance, picky eating, food neophobia, and fear of swallowing were included as diagnostic items to cover the heterogeneity of ARFID presentations (APA, 2013).

Eating Disorder Examination-Questionnaire adapted for Children (ChEDE-Q). The ChEDE-Q (Hilbert et al., 2013; Goldschmidt, Doyle, & Wilfley, 2007) is a self-report instrument assessing the specific psychopathology and key behaviors of eating disorders. Beyond 6 items on key behaviors of eating disorders, 22 items address restraint and eating, weight, and shape concern, scored on a 7-point scale ranging from 0 = *never/not at all* to 6 =

every day/extremely. Mean subscale scores were calculated, with higher values indicating greater psychopathology. For the current sample, Cronbach's α were .74 to .92 for the subscales. As the ChEDE-Q was administered to children older than 10.50 years only due to reasons of limiting the assessment burden on younger children and increasing the measure's reliability, a total of *n* = 392 children (49.1%) provided data on the ChEDE-Q.

Body Esteem Scale (BES). The 12-item appearance subscale of the child version of the BES (Forrester-Knaus, Perren, & Alsaker, 2012; Mendelson, Mendelson, & White, 2001) was used to assess children's overall evaluation of their appearance. All items were rated on a 4-point Likert scale (1 = *strongly disagree* to 4 = *strongly agree*) with higher values indicating higher body esteem. In this study Cronbach's α was .87. Due to organizational reasons of the study, a total of *n* = 597 children (74.7%) provided data on the BES.

Child Feeding Questionnaire (CFQ). The 31-item CFQ (Birch et al., 2001; Schmidt et al., 2017) assesses the parent's view of three child feeding practices and four aspects of perceptions and concerns regarding feeding and weight. For the present study, only the three subscales measuring parental feeding practices were analyzed. They assess restriction (e.g., "I intentionally keep some food out of my child's reach"), pressure to eat (e.g., "I have to be especially careful to make sure my child eats enough"), and monitoring (e.g., "How much do you keep track of the sweet things your child eats?"). Depending on the subscale, all items are rated on a 5-point Likert scale expressing agreement (1 = *disagree* to 5 = *agree*) or frequency (1 = *never* to 5 = *always*). Subscale mean scores are computed, with higher scores indicating greater use. In the current sample, Cronbach's α were .80 to .89 for the subscales. A total of *n* = 799 mothers (100%) provided data on the CFQ.

Strengths and Difficulties Questionnaire (SDQ). Children's psychosocial functioning was assessed with the parent version of the SDQ (Goodman, 1997; Klasen, Woerner, Rothenberger, & Goodman, 2003). The SDQ is a widely used screening questionnaire for positive and negative behavioral attributes of 3-16 year old children and adolescents. A total of 25 items were rated on a 3-point Likert scale (0 = *not true*, 1 = *somewhat true*, 2 = *certainly true*), allocated to five scales: emotional symptoms, hyperactivity, peer problems, conduct problems, and prosocial behavior. By summing the scores from all scales except the prosocial scale the total difficulties score is generated, ranging from 0 to 40 with higher scores indicating greater problem behavior. In this study, Cronbach's α for the total difficulties score was .69. A total of n = 788 mothers (98.6%) provided data on the SDQ.

Anthropometry. In addition to children's objectively measured weight and height, the head circumference as an indicator of brain size and malnutrition as well as children's waist-to-height ratio and a triceps skinfold measure as indicators of body fatness were determined during physical examination by trained assessors. Anthropometric data were transformed into SDSs according to national age- and sex-specific reference data (Neuhauser, Schienkiewitz, Rosario, Dortschy, & Kurth, 2013).

Statistical Analysis

For identifying underlying mutually exclusive clusters of restrictive eating patterns (classes) based on observable variables (indicators), LCA was used. In order to consider effects of maturation on the presence of restrictive eating behaviors and shape concern, the total sample was split into three age groups (age group 1: 7.5-9.5 years, age group 2: 10.0-12.0 years, age group 3: 12.5-14.5 years). LCAs were performed for each age group separately, using the same set of indicators. Model indicators were derived from the EDY-Q based on dichotomizing children's responses into "presence" (EDY-Q ≥ 4) or "absence" (EDY-Q < 4) of restrictive eating behaviors and shape concern as recently reported by Kurz et al. (2015). Considering the recommendation to include a minimum of 5 indicators in LCA which are theory-based selected and non-redundant (Wurpts & Geiser, 2014), 6 of the 8 items on restrictive eating behaviors and 1 of 2 items assessing body image disturbance were included in the model. The item assessing fear of swallowing was excluded due to its conceptual overlap with fear of choking (Kurz et al, 2016). Similarly, only 1 item assessing body image disturbances was included ("Feeling fat, while others disagree") based on aspects of item construction (positive versus negative wording) and content (shape concern versus importance of weight and shape). The item on disinterest in eating/food was excluded due to high bivariate residuals with other indicators (see below). Thus, the following dichotomous indicators remained in the model: general food avoidance, emotional food avoidance, picky eating, food neophobia, sensory food avoidance, fear of choking or vomiting, and shape concern (see Table 1). Child sex and weight status were included as covariates.

LCA was performed specifying 1-7 clusters. The most parsimonious number of latent classes was determined by examining the Bayesian Information Criterion (BIC; Schwarz, 1978), the Akaike Information Criterion (AIC; Akaike, 1974), and the AIC3 with lower values indicating better model fit. Evidence indicated that the AIC3 should be prioritized over the BIC and AIC in case that model fit statistics are equivocal (Fonseca & Cardoso, 2007). In addition to global measures of model fit, bivariate residuals as local fit indices were examined with values < 3.84 indicating conditional independence (Vermount & Madison, 2005). Entropy values were evaluated with values of .40, .60, .80, and 1.00 indicating low, medium, high, and perfect classification accuracy, respectively (Clark & Muthen, 2009). After determining the number of clusters, children were assigned to a cluster on the basis of their highest probability. Average posterior class probabilities (AvePP) were determined to evaluate the specific classification uncertainty for each of the classes with probabilities greater than .70 (Nagin, 2005) or .80 (Andruff, Carraro, Thompson, Gaudreau, & Louvet, 2009), respectively, indicating adequate separation and classification precision. LCA was carried out using Latent Gold Version 4.5 (Vermount & Madison, 2005).

Multivariate analyses of variance (MANOVAs) and χ^2 tests were used to compare and validate the identified clusters. In terms of violation of normality and homogeneity of variances, non-parametric tests were conducted, but only reported if deviating from parametric test results. Post-hoc tests with Bonferroni correction were applied to examine pair-wise differences if omnibus tests were significant. In total, four separate MANOVAs were run including sociodemographic (age, sex, social status), anthropometric (BMI-SDS, SDS of height, weight, and head, waist-to-height ratio and triceps skinfold), and clinical characteristics reported by children (ChEDE-Q subscales, BES) and parents (SDQ, CFQ) because of varying sample sizes. In addition, clusters were compared based on their prevalence of children reporting ARFID symptoms as identified through the classificatory analysis of the EDY-Q (see above).

Effect sizes for between-group differences were estimated with Cramer's φ_c or partial η^2, which can be interpreted as small (0.10 or .01), medium (0.30 or .06), or large (0.50 or .14), respectively (Cohen, 1988). All statistical analyses were performed using IBM® SPSS Statistics® version 22.0 with a two-tailed $\alpha < .05$.

Results

Latent Class Analysis: Identification of Clusters of Restrictive Eating Behaviors

LCA revealed an unambiguous 3-cluster solution across all age groups characterized by the lowest values of the AIC and AIC3, coupled with bivariate residuals close to zero (Tables S1-S3). Classification accuracy improved with greater age as indicated by increasing entropy values. Average posterior probabilities for the assignment to clusters 1, 2, and 3 were .83, .81, and .88 for age group 7.5-9.5 years, .84, .87, and .91 for age group 10.0-12.0 years, and .96, .98, and .99 for age group 12.5-14.5 years, respectively, suggesting low classification error. Figure 1 depicts the profile plots of the 3 clusters for each age group characterized by their probability scores of indicator variables.

=== Please insert Figure 1 ===

=== Please insert Figure 2 ===

=== Please insert Figure 3 ===

Across all age groups, the identified classes were labelled as "Lowly restrictive eaters without shape concern" (Cluster 1), "Highly restrictive eaters without shape concern" (Cluster 2), and "Highly restrictive eaters with shape concern" (Cluster 3), although each cluster profile showed some age-specific characteristics which are described as follows:

For age group 7.5-9.5 years, Cluster 1 was characterized by low probabilities to report restrictive eating behaviors throughout (0.00 < probability ≤ 0.21) except for a medium-sized probability of picky eating (0.34), while shape concern was almost absent (0.02). Cluster 2 was characterized by high probabilities of many restrictive eating behaviors (0.45 < probability ≤ 0.64) except for general (0.13) and anxiety-related (0.17) food restriction. Cluster 2's probability of shape concern was low (0.18). Cluster 3 was characterized by low probabilities of most restrictive eating behaviors (0.17 < probability ≤ 0.27), except for a high probability of emotional food avoidance (0.63), and high probability of shape concern (0.52).

For age group 10.0-12.0 years, Cluster 1 had very low probabilities of restrictive eating behaviors throughout (0.00 < probability ≤ 0.08) coupled with absent shape concern (0.01). High probabilities of restrictive eating behaviors in Cluster 2 referred only to food neophobia (0.45) and picky eating (0.65), while other restrictive eating behaviors were rarely present (≤ 0.28) and shape concern completely absent (0.00). Cluster 3 was characterized by medium-sized probabilities of many restrictive eating behaviors (0.28 < probability ≤ 0.44) and a high probability of shape concern (0.73).

For age group 12.5-14.5 years, Cluster 1 was characterized by almost absent to rarely prevalent restrictive eating behaviors (0.01 < probability ≤ 0.25) and a low probability of shape concern (0.21). Cluster 2 was predominately described by high probabilities of picky eating (0.68) and food neophobia (0.87), while shape concern was virtually absent (0.01). Cluster 3 was characterized by high probabilities of emotional food avoidance (0.61), picky eating (0.71), and food neophobia (0.90), coupled with a very high probability of shape concern (0.97).

Validation of Latent Classes

Because the number and main characteristics of classes were consistent across age groups, their combined data were used for validation analyses. As shown in Table 2, the 3 clusters differed with respect to sociodemographics, $F(4, 1544) = 8.403$, $p < .001$, anthropometric characteristics, $F(16, 1566) = 15.002$, $p < .001$, and clinical variables as reported by children, $F(10, 772) = 11.815$, $p < .001$, and parents, $F(8, 1566) = 10.469$, $p < .001$. Univariate analyses revealed that children from Cluster 2 were significantly younger than those from Cluster 1 and 3 ($p < .001$) and that significantly more boys were classified into Cluster 1 and 2 than 3 ($p < .001$). Cluster 3 had a lower socio-economic status than Cluster 2 ($p < .001$). Regarding children's BMI-SDS, all groups differed significantly from each other with Cluster 2 and 3 having the lowest and highest values, respectively (all *p*s < .001). Cluster 3 showed higher head SDS, greater triceps skin fold SDS and a greater waist-to-height ratio than Cluster 1 and 2 (all *p*s < .001) which did not differ significantly.

=== Please insert Table 2 ===

Clinically, parents of children from Cluster 3 reported significantly lower levels of their children's psychosocial functioning than those of Cluster 1 (p = .006) and 2 (p = .024). Regarding parental feeding practices, parents of children from Cluster 3 used more restriction, less pressure to eat, and more monitoring than parents of children from Cluster 1 and 2 (all *p*s < .001), which revealed comparable scores. Based on self-report, children from Cluster 3 showed greater levels of eating disorder psychopathology than those from Cluster 1 and 2 throughout, based on ChEDE-Q subscale scores and the BES mean score (all *p*s < .001).

Prevalence of ARFID symptoms

The prevalence of ARFID symptoms in the total sample was 5.5% (n = 44) with n = 33 (75.0%) of them being classified as normal weight, n = 8 (18.2%) as underweight, and n = 3 (6.8%) as severely underweight. Thus, ARFID symptoms coupled with objectively measured underweight was present in n = 11 of 799 children (1.4%). Table 3 shows the prevalence of ARFID symptoms as a function of cluster membership across age groups. Notably, across age groups, Cluster 3 did not include any children reporting ARFID symptoms. Except for the age group 7.5-9.5 years for which no group differences were observed, Cluster 1 and 2 differed significantly in ARFID symptom prevalence with Cluster 2 showing higher prevalences (all *p*s <.001).

As the classification accuracy of LCA in age group 7.5-9.5 years was generally lower than in other age groups, it was evaluated whether group differences in ARFID symptoms would be more pronounced in children who were certainly classified to their respective class as indicated by posterior probabilities greater than .80 (Andruff, 2009). The results indicated that including only children with high classification accuracy was associated with significant group differences in ARFID symptom prevalence between Cluster 1 and 2 across all age groups.

=== Please insert Table 3 ===

Discussion

Although restrictive eating behaviors are very common during early childhood, there is a paucity of research in older children and the motivations driving children to eat restrictively. In an attempt to classify children based on restrictive eating behaviors including recently proposed presentations of inadequate food intake (e.g., emotional food avoidance, food- or eating-related anxiety; Bryant-Waugh et al., 2010) while considering children’s body image disturbances, the present study revealed 3 clusters of child eating behaviors using LCA. Importantly, the identified clusters differed in most of the sociodemographic and anthropometric parameters, eating disorder psychopathology, parental feeding practices as well as in the proportion of children meeting ARFID symptoms, thus extending the little available evidence on the heterogeneity of restrictive eating behaviors and, more specifically, their associations with ARFID in non-clinical samples (Kurz et al., 2015, 2016).

The identified 3-cluster solution is consistent with a previous classificatory analysis of a range of different restrictive eating behaviors in 4-7 year old children from the community (Equit et al., 2013), although cluster sample sizes were slightly different. In the present study, more than half of the children (59%, Cluster 1) were classified into the “Lowly restrictive eaters without shape concern” cluster, i.e., these children were less likely to report restrictive eating behaviors and shape concern, which is comparable with the study by Equit et al. (2013) who categorized 61% as healthy eaters. The high prevalence of clusters characterized by highly (Cluster 2, 27%; Cluster 3, 14%) prevalent restrictive eating behaviors is largely in line with previous studies in children across a wide age range (see Taylor et al., 2015). However, our study revealed that the presence of shape concern was the key differentiator between Cluster 2 and 3, similar to the finding in a clinical eating disorder sample by Pinhas et al. (2017) who identified two clusters with high levels of food restriction, but distinct patterns of body image disturbances. Compared to the LCA by Equit et al. (2013), there was a larger subgroup of children reporting restrictive eating behaviors coupled with shape concern (14% versus 5%) which might be attributed to higher age in this study's sample.

According to cluster validation analyses, Cluster 2 included younger children compared to Cluster 1 and 3, which is consistent with recently identified sociodemographic correlates of selective eaters (e.g., Equit et al., 2013; Zucker et al., 2015). The fact that Cluster 2 was related to higher socio-economic status than Cluster 3 supported previous findings in picky eaters (e.g., Taylor et al., 2015) and findings indicating a negative association between socio-economic status and weight status (Gibbs & Forste, 2013). Based on children's raw height and weight measures, Cluster 2 had the lowest scores across clusters, although the respective SDSs were within the normal range, indicating that children from Cluster 2 did not show an absolute, but comparative developmental delay only. Importantly, children from Cluster 2 showed negative and the lowest SDS of BMI of all clusters, strengthening previous evidence on the association between selective eating and lower weight status (Antoniou et al., 2016; Cole et al., 2017). On the contrary, children from Cluster 3, who reported restrictive eating behaviors in combination with shape concern, had a mean of 1.4 BMI-SDS, i.e., a mean approaching overweight status. This is consistent with findings demonstrating a positive relationship between weight status and concern with weight and shape in adolescents (e.g., Calzo et al., 2012). Based on these opposing results of the two subgroups of children with restrictive eating behaviors, the study might contribute to a better understanding of why extant evidence on the association between restrictive eating behaviors and weight status in children was unclear so far (Brown, Vander Schaaf, Cohen, Irby, & Skelton, 2016). Along with children's weight and height, objectively measured circumference of children's head, waist-to-height ratio as well as triceps skin fold, widely recommended, important indicators for evaluating children's growth, were assessed; thus providing a more fine-grained analysis of bodily parameters of restrictive eaters than previous studies which focused on children's BMI only. For example, in line with evidence on positive associations between head circumference and weight status (Ivanovic et al., 2004), Cluster 3 revealed the highest head SDS of all clusters.

Psychologically, children from Cluster 2 reported comparable, low levels of eating disorder psychopathology and high levels of body esteem as Cluster 1, which is in line with findings by Jacobi et al. (2008). However, contrasting previous findings in 1.5-5 year (Machado et al., 2016) and 8-12 year old children with picky versus non-picky eating (Jacobi et al., 2008), Cluster 1 and 2 did not differ in children's psychosocial functioning as reported by parents. Methodological variations, such as self- versus parent-report and statistical analyses to determine selective eating, might account for the differences. Importantly, Cluster 3 was characterized by increased eating disorder and general psychopathology suggesting that this variant of early-onset restrictive eating behaviors was likely driven by body image concern. As evidence on the association between restrictive eating behaviors and eating disorder psychopathology is virtually lacking (Jacobi et al., 2008), future studies are recommended to further examine this relationship more comprehensively in order to elucidate their temporal course. Whether children who eat restrictively during middle childhood are at greater risk for the onset of adolescent or adult eating disorders, such as AN, is currently unclear (Kotler, Cohen, Davies, Pine, & Walsh, 2001; Marchi & Cohen, 1990; Nicholls & Viner, 2009).

The fact that symptoms of ARFID were more prevalent in children from Cluster 2 than Cluster 1 and 3 is consistent with the definitional features of ARFID (APA, 2013), thus validating the cluster solution. Especially in the age group 12.5-14.5 years, the prevalence of ARFID symptoms in Cluster 2 was high (21%) which may mirror the high classification accuracy in this age group. The present study indicated that the profile of restrictive eating behaviors and related ARFID symptoms in children from the general population became clearer and more accurate with higher child age. Given that restrictive eating behaviors, such as picky eating and food neophobia, are considered developmentally normative for early childhood, it is not surprising that these indicators did not discriminate very well between lowly and highly restrictive eaters at age 7.5-9.5 years, but at the older ages. However, the study revealed that children could be consistently subtyped according to the presence restrictive eating behaviors and body image disturbances in middle childhood just as pre-adolescence.

The multivariate effect of parental feeding strategies on cluster membership was driven by parents of children from Cluster 3 who used significantly more restriction and monitoring coupled with less pressure to eat compared to Cluster 1 and 2, a pattern that was reliably found for parents of overweight children (e.g., Schmidt et al., 2017). Parents of children from Cluster 2 reported similar feeding strategies as parents of children from Cluster 1 which contradicted previous studies comparing picky versus non-picky eaters in 4- and 5-year old children (Antoniou et al., 2016; Tharner et al., 2014). As comparisons of parental feeding practices across a wide child age might be methodologically contaminated (Schmidt et al., 2017), the present results can hardly be compared to extant findings in pre-school children.

Strengths of the study include the large sample size, the objective assessment of a range of anthropometric parameters and the use of established parent and self-report measures, as well as the analysis of different restrictive eating behaviors in middle childhood. Among the limitations, first, the use of child self-report for determining restrictive eating behaviors and ARFID symptoms necessitates careful conclusions. Although a standardized interview-based assessment of ARFID is currently receiving validation (Schmidt et al., in preparation), there was no alternative measure available at the conduct of this study for identification of ARFID symptoms in the community. As ARFID is suggested to subsume a wide range of clinical presentations with varying degrees of clinical severity, and as more objective indicators of ARFID symptoms, such as actual nutritional deficiency, or parent-report were lacking, it is unclear whether children with ARFID symptoms from both Cluster 1 and 2 actually fulfilled criteria for an ARFID diagnosis. However, for some eating behaviors, particularly eating- and food-related anxieties, child report may be especially valuable. Second, due to the analysis of cross-sectional data, the predictive validity of the 3 clusters on children's growth and cognitive development as well as their vulnerability to develop clinical eating disorder diagnoses needs further investigation. Third, as the sample included a high proportion of children from families with medium and high social status, the sample is not totally representative of the German population (Lampert, Kroll, Müters, & Stolzenberg, 2013). The overrepresentation of high-income families is considered to be a general recruitment bias in population-based studies (Jaddoe et al., 2010; Neermann Jacobsen, Nohr, & Frydenberg, 2010).

Conclusions

Most notably, the present study underlined the importance of considering body image disturbances in the research of restrictive eating behaviors, particularly in older children and young adolescents when concern about one's weight and shape typically emerge (Calzo et al., 2012). Given that restrictive eating behaviors without body image disturbances were not associated with general and eating disorder psychopathology, they may not necessarily be considered as a cause for parental concern. However, these children presented with low anthropometric parameters throughout and a subgroup was found to report symptoms of ARFID, placing those children likely at risk for increased malnutrition and inadequate neurological development (World Health Organization, 2010). On the other hand, children with food restriction related to shape concern may be at likely risk for increased weight status and to exhibit other inappropriate compensatory behaviors (Micali et al., 2017). Therefore, parents of children showing restrictive eating behaviors should be observant of children's growth development and motivations to eat restrictively. Longitudinal data are needed to evaluate the effects of restrictive eating behaviors on children's nutritional status, growth failure, and psychosocial impairment in the long-term.

Competing interests

The authors declare that they have no competing interests.

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Table 1. Sociodemographic and anthropometric characteristics and prevalence of self-reported restrictive eating behaviors and body image disturbances for the total sample and specific age groups

	Total sample (*N* = 799)	Age group 7.5-9.5 years (*n* = 325)	Age group 10.0-12.0 years (*n* = 286)	Age group 12.5-14.5 years (*n* = 188)	*p*	η^2/φ_c
Sociodemographics	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*		
Age (years)	10.50 (2.02)	8.41 (0.65)[a]	11.08 (0.72)[b]	13.22 (0.60)[c]	<.001	.89
Sex: female (*n*, %)	368 (46.1)	146 (44.9)	130 (45.5)	92 (48.9)	.658	.03
Winkler Index	13.41 (3.45)	13.61 (3.42)	13.38 (3.48)	13.11 (3.46)	.284	.00
Anthropometrics						
Height (cm)	146.00 (14.07)	133.26 (7.31)[a]	149.72 (8.07)[b]	162.36 (8.96)[c]	<.001	.68
Height SDS	0.25 (0.99)	0.17 (1.00)	0.32 (0.94)	0.27 (1.05)	.174	.00
Weight (kg)	40.52 (14.87)	29.37 (6.77)[a]	43.77 (12.44)[b]	54.87 (13.77)[c]	<.001	.47
Weight SDS	0.24 (1.11)	-0.07 (1.03)[a]	0.42 (1.16)[b]	0.37 (1.13)[b]	<.001	.03
BMI SDS	0.13 (1.13)	-0.12 (0.99)[a]	0.31 (1.21)[b]	0.30 (1.14)[b]	<.001	.04
Head SDS	0.04 (0.98)	0.03 (0.94)	0.10 (1.00)	-0.01 (1.02)	.494	.00
Waist-to-Height Ratio	0.44 (0.14)	0.43 (0.04)	0.45 (0.22)	0.43 (0.06)	.064	.01

	Total sample (*N* = 799)	Age group 7.5-9.5 years (*n* = 325)	Age group 10.0-12.0 years (*n* = 286)	Age group 12.5-14.5 years (*n* = 188)	*p*	η^2/φ_c
Triceps skin fold SDS	-0.09 (0.94)	-0.22 (0.89)[a]	0.04 (1.00)[b]	-0.07 (0.93)[ab]	.004	.01
Restrictive eating behaviors (*n*, %)						
General food avoidance*	47 (5.9)	27 (8.3)	12 (4.2)	8 (4.3)	.054	.09
Disinterest in food/eating	96 (12.0)	45 (13.9)	31 (10.8)	20 (10.6)	.419	.05
Emotional food avoidance*	228 (28.5)	108 (33.2)	71 (24.8)	49 (26.1)	.050	.09
Weigh too little	93 (11.6)	41 (12.6)	31 (10.8)	21 (11.2)	.771	.03
Wish to weigh more	58 (7.3)	30 (9.2)	19 (6.6)	9 (4.8)	.154	.07
Feeling fat, while others disagree*	148 (18.5)	42 (12.9)[a]	60 (21.0)[b]	45 (23.9)[b]	.003	.12
Importance of weight and shape	135 (16.9)	67 (20.6)	42 (14.7)	26 (13.8)	.065	.08
Picky eating*	293 (36.7)	127 (39.1)	98 (34.3)	68 (36.2)	.462	.04
Food neophobia*	220 (27.5)	108 (33.2)[a]	70 (24.5)[b]	42 (22.3)[b]	.010	.11
Fear of choking or vomiting*	36 (4.5)	25 (7.7)[a]	8 (2.8)[b]	3 (1.6)[b]	.001	.13
Fear of swallowing food	14 (1.8)	8 (2.5)	4 (1.4)	2 (1.1)	.433	.05
Sensory food avoidance*	121 (15.1)	64 (19.7)[a]	39 (13.6)[b]	18 (9.6)[b]	.006	.11

Note. BMI Body Mass Index; SDS Standard deviation score. The presence of restrictive eating behaviors was derived from the Eating Disorders in Youth-Questionnaire with scores ≥ 4 indicating avoidant or restrictive eating behaviors "at least often". Different superscripts indicate group differences. Statistics from univariate tests are presented. *Items used as indicators for Latent Class Analysis.

Table 2. Sociodemographic, anthropometric, and clinical characteristics of clusters identified through Latent Class Analysis

	Cluster 1 "Lowly restrictive eaters without shape concern" (n = 471)	Cluster 2 "Highly restrictive eaters without shape concern" (n = 213)	Cluster 3 "Highly restrictive eaters with shape concern" (n = 115)			
	M (SD)	*M (SD)*	*M (SD)*	*F*	*df*	*p*
Sociodemographics						
Age	10.62 (2.16)[a]	10.03 (1.85)[b]	10.72 (1.63)[a]	7.216	2, 772	.001
Winkler Index	13.65 (3.39)[a]	13.60 (3.37)[a]	12.09 (3.60)[b]	9.891	2, 772	<.001
	n (%)	*n* (%)	*n* (%)	χ^2		
Sex: female (*n*, %)	210 (44.6)[a]	87 (40.9)[a]	71 (61.7)[b]	14.123	2, *N* = 799	.001
Anthropometrics	*M (SD)*	*M (SD)*	*M (SD)*	*F*		
Height (cm)	146.81 (15.22)[a]	142.71 (12.30)[b]	148.75 (10.92)[a]	8.968	2, 789	<.001
Height SDS	0.22 (1.00)[a]	0.18 (0.99)[a]	0.52 (0.94)[b]	5.258	2, 789	.005
Weight (kg)	40.18 (15.09)[a]	35.16 (10.70)[b]	51.87 (14.60)[c]	53.702	2, 789	<.001

	Cluster 1 "Lowly restrictive eaters without shape concern" (*n* = 471)	Cluster 2 "Highly restrictive eaters without shape concern" (*n* = 213)	Cluster 3 "Highly restrictive eaters with shape concern" (*n* = 115)			
	M (SD)	*M (SD)*	*M (SD)*	*F*	*df*	*p*
Weight SDS	0.10 (1.03)[a]	-0.09 (0.97)[a]	1.40 (0.98)[b]	92.975	2, 789	<.001
BMI SDS	-0.02 (1.01)[a]	-0.25 (0.95)[b]	1.46 (0.93)[c]	127.049	2, 789	<.001
Head SDS	0.00 (0.92)[a]	-0.10 (0.99)[a]	0.49 (1.07)[b]	14.720	2, 789	<.001
Waist-to-Height Ratio	0.43 (0.17)[a]	0.42 (0.04)[a]	0.50 (0.07)[b]	13.968	2, 789	<.001
Triceps skin fold SDS	-0.21 (0.89)[a]	-0.31 (0.86)[a]	0.83 (0.77)[b]	73.236	2, 789	<.001
Clinical characteristics: child report						
ChEDE-Q Restraint	0.30 (0.70)[a]	0.20 (0.49)[a]	0.72 (0.84)[b]	11.329	2, 389	<.001
ChEDE-Q Eating Concern	0.32 (0.68)[a]	0.25 (0.36)[a]	1.19 (1.25)[b]	35.636	2, 389	<.001
ChEDE-Q Weight Concern	0.62 (1.10)[a]	0.34 (0.56)[a]	2.07 (1.39)[b]	54.371	2, 389	<.001
ChEDE-Q Shape Concern	0.64 (1.13)[a]	0.35 (0.58)[a]	2.31 (1.56)[b]	63.536	2, 389	<.001

	Cluster 1 “Lowly restrictive eaters without shape concern“ (*n* = 471)	Cluster 2 “Highly restrictive eaters without shape concern” (*n* = 213)	Cluster 3 “Highly restrictive eaters with shape concern” (*n* = 115)			
	M (SD)	*M (SD)*	*M (SD)*	*F*	*df*	*p*
Body Esteem Scale	3.18 (0.61)[a]	3.25 (0.49)[a]	2.50 (0.72)[b]	56.061	2, 594	<.001
Clinical characteristics: parent report						
CFQ Restriction	2.24 (0.91)[a]	2.22 (0.88)[a]	2.93 (0.91)[b]	29.307	2, 788	<.001
CFQ Pressure to eat	1.79 (0.92)[a]	1.96 (0.96)[a]	1.51 (0.68)[b]	9.293	2, 788	<.001
CFQ Monitoring	3.34 (1.05)[a]	3.30 (1.07)[a]	3.78 (0.90)[b]	9.743	2, 788	<.001
SDQ Total	8.64 (5.88)[a]	8.72 (5.57)[a]	10.53 (6.30)[b]	4.994	2, 788	.007

Note. ARFID Avoidant/restrictive food intake disorder; CHEDE-Q Child Eating Disorder Examination-Questionnaire; CFQ Child Feeding Questionnaire; SDQ Strengths and Difficulties Questionnaire; SDS Standard deviation score. Different superscripts indicate group differences. Statistics from univariate tests are presented.

Table 3. Prevalence of ARFID symptoms (*n*, %) across clusters and age groups

	Total age group	Cluster 1	Cluster 2	Cluster 3	χ		*p*	φ_c
Age group 7.5-9.5 years, *n* = 325								
ARFID symptoms: yes	21 (6.5)	14 (6.9)	7 (7.4)	0 (0.0)	2.058	df = 2, *N* = 325	.357	.08
Certainly classified children, n = 199								
ARFID symptoms: yes	7 (3.5)	2 (1.6)	5 (9.6)	0 (0.0)	7.854	df = 2, *N* = 199	.020	.20
Age group 10.0-12.0 years, *n* = 286								
ARFID symptoms: yes	14 (4.9)	2 (1.6)	12 (13.3)	0 (0.0)	20.352	df = 2, *N* = 286	<.001	.27
Certainly classified children, n = 237								
ARFID symptoms: yes	11 (4.6)	0 (0.0)	11 (15.3)	0 (0.0)	26.435	df = 2, *N* = 237	<.001	.33
Age group 12.5-14.5 years, *n* = 188								
ARFID symptoms: yes	9 (4.8)	3 (2.1)	6 (21.4)	0 (0.0)	20.107	df = 2, *N* = 188	<.001	.33
Certainly classified children, n = 184								
ARFID symptoms: yes	9 (4.9)	3 (2.1)	6 (21.4)	0 (0.0)	19.537	df = 2, *N* = 184	<.001	.33

Note. Certainly classified children include only those with posterior classification probabilities ≥ .80 in Latent Class Analysis indicating high classification accuracy

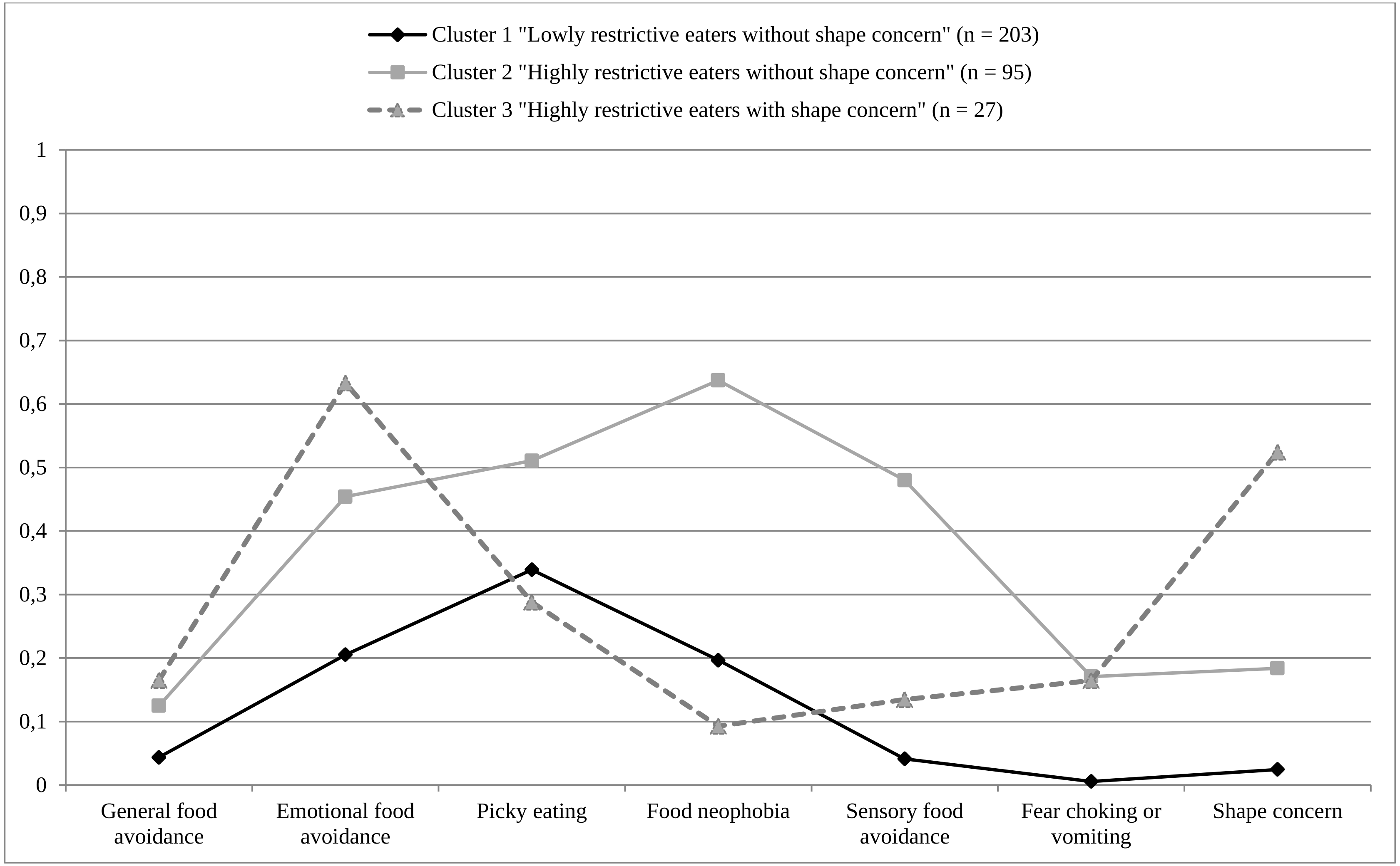

Figure 1. Profile plot of restrictive eating behaviors classes based on their probability scores to exhibit specific restrictive eating behaviors and shape concern in children aged 7.5-9.5 years

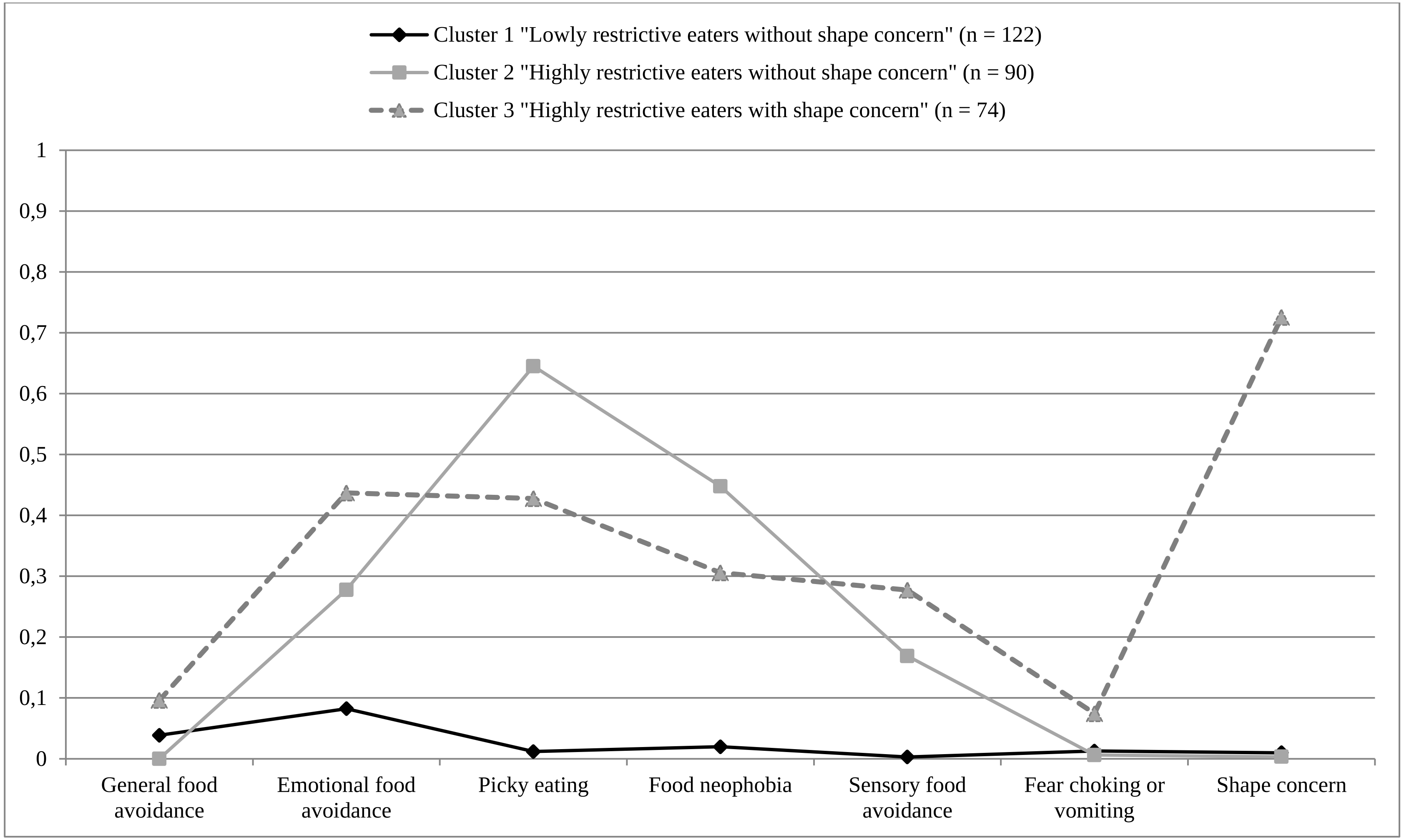

Figure 2. Profile plot of restrictive eating behaviors classes based on their probability scores to exhibit specific restrictive eating behaviors and shape concern in children aged 10.0-12.0 years

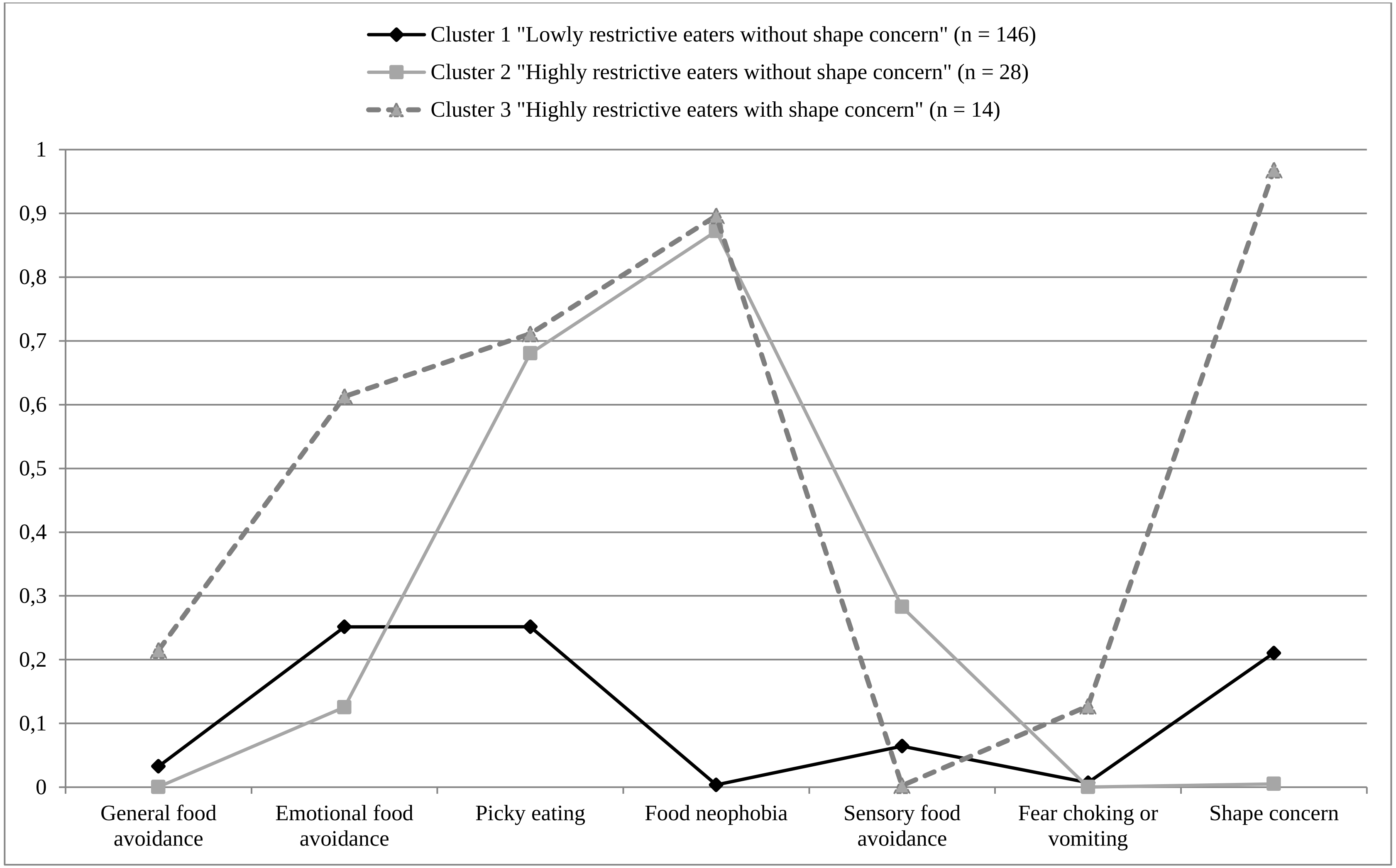

Figure 3. Profile plot of restrictive eating behaviors classes based on their probability scores to exhibit specific restrictive eating behaviors and shape concern in children aged 12.5-14.5 years

Table S1. Fit indices for Latent Class Analysis in children aged 7.5-9.5 years (*n* = 325)

Number of classes	BIC	AIC	AIC3	Entropy	*N* parameters	LL	df	*p*
1	**2238.19**	2207.92	2215.92	1.00	8	-1095.96	317	0.019
2	2246.08	2174.18	2193.18	0.43	19	-1068.09	306	0.34
3	2267.66	**2154.15**	**2184.15**	0.53	30	-1047.07	295	0.81
4	2315.27	2160.14	2201.14	0.55	41	-1039.07	284	0.87
5	2364.26	2167.50	2219.50	0.65	52	-1031.75	273	0.90
6	2420.02	2181.64	2244.64	0.64	63	-1027.82	262	0.88
7	2471.98	2191.98	2265.98	0.62	74	-1021.99	251	0.89

Note. BIC Bayesian Information Criterion; AIC Akaike Information Criterion; LL = Log-Likelihood. Best-fitting models are depicted in bold. Higher entropy values indicate better classification accuracy.

Table S2. Fit indices for Latent Class Analysis in children aged 10.0-12.0 years (*n* = 286)

Number of classes	BIC	AIC	AIC3	Entropy	*N* parameters	LL	df	*p*
1	1727.64	1698.39	1706.39	1.00	8	-841.20	278	0.89
2	**1705.86**	1640.05	1658.05	0.63	18	-802.03	268	1.00
3	1718.58	**1616.22**	**1644.22**	0.65	28	-780.11	258	1.00
4	1763.82	1624.90	1662.90	0.67	38	-774.45	248	1.00
5	1811.38	1635.89	1683.89	0.70	48	-769.94	238	1.00
6	1855.41	1643.36	1701.36	0.69	58	-763.68	228	1.00
7	1904.60	1656.00	1724.00	0.73	68	-760.00	218	1.00

Note. BIC Bayesian Information Criterion; AIC Akaike Information Criterion; LL = Log-Likelihood. Best-fitting models are depicted in bold. Higher entropy values indicate better classification accuracy.

Table S3. Fit indices for Latent Class Analysis in children aged 12.5-14.5 years (*n* = 188)

Number of classes	BIC	AIC	AIC3	Entropy	*N* parameters	LL	df	*p*
1	**1124.24**	1098.35	1106.35	1.00	8	-541.18	180	0.62
2	1138.05	1079.80	1097.80	0.55	18	-521.90	170	0.98
3	1151.20	**1060.58**	**1088.58**	0.83	28	-502.29	160	1.00
4	1183.95	1060.97	1098.97	0.82	38	-492.49	150	1.00
5	1229.55	1074.20	1122.20	0.67	48	-489.10	140	1.00
6	1265.67	1077.96	1135.96	0.73	58	-480.98	130	1.00
7	1309.61	1089.53	1157.53	0.81	68	-476.77	120	1.00

Note. BIC Bayesian Information Criterion; AIC Akaike Information Criterion; LL = Log-Likelihood. Best-fitting models are depicted in bold. Higher entropy values indicate better classification accuracy.