Physical Activity, Sedentary Behavior, and Dietary Patterns among Children

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Abstract Energy balance-related behavioral patterns find their origin in early childhood. The current paper provides an overview of studies that have examined such behavioral patterns, i.e., the clustering of dietary behaviors, physical activity, and/or sedentary behavior. The paper discusses the importance of examining energy balance-related behavioral patterns in children, outlines methods to examine these patterns, and provides examples of patterns that have been found (e.g., the universal sedentary-snacking and healthy intake patterns, as well as more unique or local patterns), child and parental characteristics predicting such patterns (e.g., child gender and maternal educational level), and the relationship of these patterns with overweight and related measures.

Keywords Activity pattern · Behavioral pattern · Child · Clustering · Cluster analysis · Dietary intake · Dietary pattern · Eating routines · Energy balance · Factor analysis · Lifestyle pattern · Obesity · Overweight · Physical activity · Principal component analysis · Sedentary behavior

Introduction

Globally, at least 42 million children under age 5 years were overweight in 2010, and these numbers will continue to increase [1]. Childhood overweight is a major risk factor for several chronic conditions, such as cardiovascular diseases and type 2 diabetes mellitus [2]. Moreover, childhood overweight is known to track into adulthood, indicating that overweight children often remain overweight or become obese during later life [3].

Weight gain is the result of a positive energy balance, with energy intake exceeding energy expenditure [2]. Behaviors that may influence the energy balance have been referred to as "energy balance-related behaviors" (EBRBs) [4]. In children and adolescents, the most important behavioral determinants of overweight include consumption of energy-dense foods, low levels of physical activity. and frequent television viewing and computer use [5]. Dietary and physical activity habits are formed at early life stages [6, 7] and have been said to track into later life [8], indicating the urgency of increasing our understanding of the origin and development of EBRBs in children.

In addition to the examination of various separate behaviors related to overweight, various studies have examined the co-occurrence or "clustering" of EBRBs in children. Clusters are combinations of behaviors that are more prevalent than would be expected from the prevalence of the individual behaviors [9] and also are called behavioral patterns. The current paper provides an overview of studies that have examined EBRB patterns. Rather than aiming to be exhaustive, our goal was to use the results of our review as a basis to discuss the importance of examining such behavioral patterns in children, outline methods to examine these patterns, and provide examples of patterns that have been found, child and parental characteristics predicting such patterns, and their relationship with overweight.

Why Do we Need to Examine Behavioral Patterns in Children?

Traditionally, research into EBRBs and their effects on overweight and other health parameters has been focused on single behaviours [10•]. However, not single behaviours but the combination of multiple risk behaviours determines whether an individual is at a high risk to develop overweight or obesity [5]. The traditional approach in studies regarding EBRBs has various limitations, including failing to account for colinearity or synergy between behaviors and the inability to detect small effects of single behaviors on health outcomes, such as overweight and obesity [10•, 11]. Furthermore, obesogenic behaviors (i.e., behaviors promoting obesity, e.g., sedentary behavior,

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unhealthy nutrition) might be compensated by leptogenic behaviors (i.e., healthy behaviors, preventing obesity; e.g., physical activity, healthy nutrition) on the other side of the energy balance, which is ignored when looking at single behaviors. Finally, clustered behaviors often share determinants [12••, 13], and by targeting these determinants, multiple behaviors within the same cluster can be addressed simultaneously. By identifying factors associated with behavioral patterns, high-risk groups for preventive interventions can be identified.

Identifying behavioral patterns already in young children is important, because dietary and physical activity (PA) habits are formed in the early life stages [7, 8], and these patterns even track into adulthood [14, 15]. This means that adult lifestyle often is already established during childhood. Preventive efforts will thus need to target children at a very young age, before clustered obesogenic behaviors have rooted in the child's habits. We therefore plead for focusing on patterns rather than on single behaviors in childhood. The rapidly increasing knowledge base in this area demonstrates the increased attention that behavioral patterns are receiving.
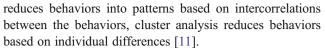
Based on the existence of clustered behaviors, overweight prevention efforts will need to apply an integrated obesity prevention approach, using the potential synergy between EBRBs, for example by addressing multiple behaviors simultaneously [16]. An example of a preventive intervention taking into account clustering of EBRBs is that parents could be advised not to offer unhealthy snacks to the child when watching television to prevent television watching from becoming a cue for unhealthy snacking.

Methods of Pattern Analyses

Various methods have been used to examine and measure behavioral patterns. Of course, one could choose to assess behavioral patterns based on theory or guidelines, a method that often is applied when assessing dietary intake [11]. Examples of such rankings are the Healthy Eating Index [17] and similar indexes [18, 19]. However, the large variety of such indexes reflects the lack of consensus regarding the behaviors to be included and the weighing of these behaviors. Empirically derived behavioral patterns avoid this problem, as they are not defined a priori and do not depend on how the authors define a (healthful) pattern. Rather, statistical methods are used to generate these patterns [11]. The current paper will focus on such empirically derived patterns.

Statistical Methods: Factor Analyses vs. Clustering Analyses

Factor analyses and cluster analyses are both frequently used and validated methods to examine the existence of behavioral patterns [20, 21]. However, while factor analysis reduces behaviors into patterns based on intercorrelations between the behaviors, cluster analysis reduces behaviors based on individual differences [11].

Although factor and cluster analyses use different analytical techniques and there are clear differences in approaches and interpretations, the underlying behavioral patterns often are revealed by either method [11]. We therefore will further address both factor and cluster analyses as "pattern analyses." These pattern analyses have various limitations, which will be described in more detail below. For an extensive comparison of both techniques in examining dietary patterns, we recommend the review by Newby and colleagues [11].

Subjective Decisions

Both factor analysis and cluster analysis rely on various subjective choices that may influence the outcomes in terms of both the number and type of patterns derived. Even the naming of the patterns is subjective, as authors often choose the most eye-catching behaviors included to characterize their patterns, due to an inability to summarize a whole pattern in a single name. For instance, Shin and colleagues reported an "animal foods" pattern, but this pattern also included intake of nonanimal foods, such as noodles and sweet drinks [22].

Another subjective choice to be made is the cutoff point for component loadings when using factor analyses. Cutoff points in various studies among children have been found to vary from 0.2 to 0.45 [22–24]. Different cutoff points lead to different patterns; both cutoffs that are too strict and cutoffs that are not strict enough lead to noninformative patterns. Too strict cutoffs lead to very narrow patterns that are hardly more informative than single behaviors, whereas too lenient cutoffs lead to patterns that include such a broad range of behaviors that they are not interpretable. In line with other authors [25], and based on our empirical experience [12••, 13], we recommend the use of a cutoff of 0.4 for component loadings. Nevertheless, the findings of pattern analyses are of an indicative nature and further examination of cross-behavioral clustering of energy balance-related behaviors in children is needed.

Input Variables

The choice of input variables for the analyses holds important implications for the results. First of all, one has to decide on the level of detail and the number of input variables. An interesting example of this comes from the inclusion of physical activity in EBRB pattern analyses in young children. The vast majority of existing studies focus on one or two measures to summarize physical activity and/or sedentary behavior. However, some studies have differentiated between several PA types (e.g., between active transport, sports, and playing outside) and found that these different

types clustered within different behavioral patterns [12••, 13, 26••]. With regard to sedentary behavior, television viewing and computer use were found to cluster within different patterns, showing the importance of assessing these behaviors separately as well, and not as one measure of sedentary behavior [12••]. Another reason to assess screen-based behaviors separately is that previous research has reported television use in youngsters to be negatively, not positively, associated with other sedentary behaviors, including computer use [27]. Furthermore, a new category of screen-based behavior has become increasingly important during the past years: nonsedentary screen-based behaviors, such as active gaming or exergaming [28]. As yet it is unclear how these novel behaviors cluster with other EBRBs. These examples demonstrate the importance of the level of detail of input behaviors for behavior pattern analyses.

However, more level of detail is not necessarily better. This is reflected by pattern studies regarding dietary intake. Most studies use food groups to further collapse dietary intake data (e.g., combining all vegetables into one sum score item) or assess only a limited number of dietary intake behaviors [11]. The choices of which food items to assess, whether or not to group them, and if grouped into which food groups are all subjective choices influencing the findings. In addition, the authors must decide how to quantify the input data: using amount, frequency, energy, percentage of total energy consumed (thus correcting for total energy intake), or z-scores (reflecting individual deviations from the mean of the sample). All of these options have advantages and disadvantages [11]. The choice needs to fit with the research question of the specific study and further depends on the items to be included: there is no "one size fits all" approach. Although it is perfectly sensible to measure snack intake using calories, for instance, it makes no sense to measure water in this way.

Nutrition provides another challenge with regard to the input variables for patterns analyses. Most pattern studies use measures of *dietary intake* in their pattern analyses, i.e., focusing on what was eaten, ignoring information regarding the context in which these items were consumed, i.e., a child's *eating routines*. Eating routines provide information regarding how, where, when, and with whom the intake behaviors occur. Gubbels and colleagues included a wide range of such eating routines in their study of EBRB patterns among young children [12••]. The fact that in this particular study all of these eating routines clustered with activity-related behaviors and/or other eating routines shows the value of moving beyond interpreting someone's diet as merely what that person consumes. It shows the importance of incorporating the context of dietary intake behaviors to establish a more informative typology of children scoring high on a particular pattern. At a methodological level, the inclusion of eating routines in addition to dietary intake increases the compatibility with activity-related behavior measures, which also tend to include the context (e.g., differentiating between sports at school and at a sports club) [12••, 13].

A final issue that is apparent with respect to the input variables is their actual assessment. Most studies use questionnaires to assess the input variables. In the case of children, such questionnaires often are filled out by parents. This possibly introduces bias. Some scholars have suggested the use of accelerometry instead of self-report data when examining activity patterns [29]. However, although accelerometer data provide objective data regarding the intensity and duration of activities, they often cannot distinguish between different activity types [30] and thus are less suitable for most clustering studies. However, recent studies have shown promising results in using pattern recognition of accelerometer data to differentiate between different activity types [31]. Accelerometers might become very valuable for future clustering studies. In addition, novel technologies, such as computerized assessment of dietary intake using smart phones for instance, are promising new methods to improve dietary assessment quality [32].

Dietary Patterns

Numerous studies have examined dietary patterns in youngsters. A few examples will be described here. Several "universal" patterns have been found across studies in various countries and in various age groups. An example of such a universal pattern is a pattern that includes high intake of healthful foods, such as fruit, vegetables, and fish [13–15, 22, 24, 33–39]. Such a healthy intake pattern characterizes a diet that is high in dietary fibers and unsaturated fats and low in saturated fats and refined sugars. There is convincing evidence that the dietary behaviors that these patterns consist of are protective against the development of overweight and obesity [40]. On the other side, various studies from all over the world report patterns combining high intake of snacks and other unhealthy energy-dense foods [15, 16, 22, 24, 33–35, 38, 39, 41–45], increasing overweight risks [40].

In addition to the universal patterns, many studies report the existence of a "traditional" pattern [13–15, 22, 35, 39, 46, 47], of which the content is dependent on the country or region in which the study was conducted. Examples of such traditional patterns are a traditional Finnish pattern (rye, potatoes, milk, butter [14]), a British pattern (meat, potatoes [15, 35, 39, 46]), a Dutch pattern (sandwiches, potatoes, meat [13]), a Mediterranean pattern (plant foods, oil, high eating frequency [47]), and a Korean pattern (vegetables, seaweeds, beans, fruits [22]). An enormous variety of other dietary patterns has been reported, including a meat-rich

pattern [24], a protein-rich pattern (including eggs, dairy, fish, and/or meat [24, 45]), a low-cost pattern (including low-cost foods, such as potatoes and organ meats [48]), a main meal pattern [23, 48], and a sandwich pattern [13, 45].
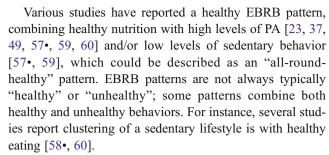
As regards clustering of eating routines, one study reported a "fast food" pattern, a pattern characterized by a high frequency of eating take-out meals, as well as a short duration of meals, thus literally fast food eaters [12••]. Kontogianni et al. [47] reported a pattern involving high breakfast consumption and a high eating frequency in children, in combination with a Mediterranean diet.

Activity Patterns

In contrast to the enormous evidence base regarding dietary intake patterns, far less studies have examined physical activity patterns. Television viewing has been found to be positively associated with computer playing [43, 49–52] and negatively with physically activity [43, 50–56]. Computer playing has been found to be negatively [52] as well as positively [12••, 26••] associated with physical activity. The latter pattern, a "sports–computer" pattern, might be explained by the competitive element involved in both sports and computer games, which appeals to certain children, but further research would be needed to confirm this hypothesis [12••]. A study by Jago et al. [26••], who examined activity-related behavior patterns in 10- and 11-year-olds, showed that the group of children having a so-called "high active–high sedentary" pattern accumulated the highest mean number of minutes of moderate to vigorous PA, even higher than the children in the high activity–low sedentary group.

Cross-Behavioral Patterns

Several studies examined cross-behavioral patterns (i.e., covering both dietary and activity-related behaviors). These studies often identify a "sedentary-snacking" pattern in children. This patterns combines intake of unhealthy food items (e.g., snacks, sweets, soft drinks, junk food) with sedentary behavior (i.e., television and/or computer use) [12••, 13, 23, 36, 37, 49, 57•, 58•, 59, 60]. This sedentary-snacking pattern is a universal behavioral pattern, found in developed countries all over the world (i.e., Europe, Asia, Australia, United States). Various plausible mechanisms behind the association between television watching and snacking have been previously proposed, including the stimulating influence of snack commercials [61], the provision of a context during sedentary activities that promotes passive snacking or overeating [62], and the distracting influence of television watching while eating, disrupting habituation to food cues (e.g., satiety) [63].

Various studies have reported a healthy EBRB pattern, combining healthy nutrition with high levels of PA [23, 37, 49, 57•, 59, 60] and/or low levels of sedentary behavior [57•, 59], which could be described as an "all-round-healthy" pattern. EBRB patterns are not always typically "healthy" or "unhealthy"; some patterns combine both healthy and unhealthy behaviors. For instance, several studies report clustering of a sedentary lifestyle is with healthy eating [58•, 60].

In contrast to the food items used in behavioral pattern analyses, which often are assessed with detailed instruments, activity behaviors often are assessed quite poorly or aggregated into one or two measures summarizing all activity behaviors (see above). Almost all cross-behavioral clustering studies described above were limited to only one measure of PA (e.g., minutes of exercise [37]). One study differentiated between moderate and vigorous PA [60]. In addition, only two studies [12••, 13] incorporated different *types* of physical activity (i.e., active transport, school sports, sports at a sports club, playing outside) in the cross-behavioral pattern analyses of young children's energy balance-related behaviors. The latter studies found that these different types of physical activity indeed clustered differently with the various behavioral patterns.

Only a few studies included eating routines in the cross-behavioral examination of lifestyle patterns in children. One study included television viewing during dinner in its analysis, in addition to television viewing in general, computer use, and physical activity [64]. Having the television on during dinner was found to cluster negatively with physical activity and positively with television viewing in general. Another study that incorporated eating routines found that eating fast food clustered with screen-based behavior, whereas breakfast and dinner frequency each clustered with certain dietary intake behaviors (e.g., vegetable intake) but not with other eating routines or activity-related behaviors [37]. Only one study included a range of eating routines [12••]. This study reported on two cross-behavioral patterns, including eating routines: first, the "Television–Snacking" pattern. Children with high scores for this pattern watched much television, often ate with the television on, had a high snacking frequency, and were more likely not to eat at the table. Another cross-behavioral pattern, including eating routines instead of dietary intake, was a so-called "Traditional Family" pattern [12••]. Children with high scores for this pattern frequently used active means of transport, did not skip meals, and often ate together with their family.

Predictors of Behavioral Patterns

To identify high-risk groups that could be targeted by preventive interventions, it is important to be able to predict

which children are likely to show which behavioral patterns. It is therefore interesting to examine the association between energy balance-related patterns and background characteristics of the children and their parents.

Children's gender has been consistently shown to be associated with their pattern scores. Boys score higher than girls on unhealthy patterns such as the sedentary-snacking [12••, 13] or unhealthy intake patterns [12••, 34, 41, 45]. On the other side, boys are also more likely to have a sporty-healthy eating pattern [60], or a high active/high sedentary behavioral pattern [58•]. Girls are more likely to have a healthy [39, 58•] or traditional [39] intake pattern.

Parents play a crucial role in the lives of children, deciding on many factors that influence EBRBs and weight gain [65, 66]. When trying to change EBRBs and prevent excessive weight gain in young children, it is therefore necessary to target parents. Regarding parental characteristics related to EBRB patterns, parental educational levels and SES are positively correlated with healthy patterns and negatively with unhealthy patterns [12••, 13, 14, 23, 24, 36, 39, 45]. Unhealthy patterns are further positively associated with parental body mass index (BMI) [12••, 13, 14, 24, 36] and negatively with maternal age [39]. An explanation for these associations could lie in the possible mediating role of parenting practices [13]. Mothers with a lower educational level or a higher BMI previously have been found to use less stimulation of healthy intake and PA [67]. Maternal working hours have been found to be inversely associated with traditional patterns [13] and positively with junk food patterns [39]. Households that have a nontraditional parental role division (i.e., a working mother) are possibly also less traditional in their eating patterns. Alternatively, working mothers might have less time to prepare traditional meals. Sons of manual workers also more often had a traditional eating pattern [35].

Behavioral Patterns, Overweight, and Related Health Indicators

Various behavioral patterns have been linked previously to overweight-related measures. A healthy behavioral pattern (high levels of PA and/or a healthy diet) was inversely associated with overweight risk [23, 37]. Seghers and Rutten [58•] found that preadolescents in a "sporty media-oriented mixed eaters" pattern performed significantly better on a fitness test than others, although they did not find any relationship between the patterns they found and weight status.

The very common sedentary-snacking pattern puts children at risk for (future) overweight, as shown in several studies [12••, 13, 23]. High levels of sedentary behavior and intake of energy-dense foods are both important risk factors for childhood obesity [5]. In line with this, a pattern combining inactivity and sedentary behavior with television viewing during meals was related to increased odds of overweight in boys [64]. Having the television on during dinner clustered negatively with physical activity and positively with television viewing in general. Children with this pattern had higher cross-sectional odds of being overweight. However, the majority of the studies have not found an association between a sedentary-snacking pattern or other patterns and overweight-related measures [33, 36, 57•, 58•, 60]. This can probably be attributed to the cross-sectional design of those studies.

Some patterns may not have such straight forward implications for overweight development based on the included behaviors, because they contain behaviors that have no clear association with overweight risk, or because they combine both healthy and unhealthy behaviors. An example of this is a sporty-computer pattern [12••], including both high levels of sports, which is linked to decreased overweight risks, and computer use, linked to increased overweight risks. In practice, an increased overweight risk was found for children scoring high on this pattern. In line with this, a growing body of evidence shows that sitting time might be more predictive of weight status and health than time spent being physically active [68–70]. Te Velde et al. [64] reported a similar finding, with the association between girls' behavioral patterns and overweight being primarily dependent on sedentary behavior within the patterns. These findings underline the importance of interventions focusing on reducing sedentary time, in addition to promoting physical activity.

Shin and colleagues [22] reported an increased overweight risk in Korean preschoolers with high scores on an animal foods cluster (including meat and fish). A traditional Korean intake pattern (including vegetables, seaweeds, beans, dairy) was further associated with a higher subjective health status. A traditional Mediterranean pattern (high breakfast consumption and a high eating frequency) was associated with decreased overweight risk [47].

Conclusions

Several universal, as well as some more local or unique behavioral patterns, have been reported. Clustering within the behavioral categories of activity behavior and dietary intake (i.e., the healthy intake and sandwich patterns), as well as across these categories (i.e., the sedentary-snacking and sporty-traditional meal patterns), has been found. Various patterns were related to overweight development. Furthermore, various parental and child background characteristics were associated with these patterns, providing indications for target groups for future childhood obesity prevention interventions. Especially children of parents with a lower SES or a

higher BMI seem important target groups. Furthermore, boys and girls show distinctly different behavioral patterns and thus may need a different preventive approach.

The findings indicate that future interventions to prevent childhood overweight may profit from addressing diet- and activity-related behaviors simultaneously, using the synergy between clustered behaviors. In addition, within behavioral categories (i.e., within eating- and activity-related routines) such interventions should address the wide range of obesogenic behaviors that are important in young children and not focus on single behaviors. An example of this is that reducing sedentary time seems at least equally important for overweight prevention as increasing physical activity.

An interesting side track from EBRB patterns is that several studies have now showed that EBRB determinants cluster as well. For example, energy balance-related parenting practices (e.g., rules about snacking) have been found to cluster [71]. Such clusters of EBRB determinants could be indicators of a wider obesogenic (family) context; insights into the clustering of determinants can help to inform the development of interventions aimed at improving the environment, within an energy balance approach. Furthermore, Kremers et al. [16] examined the clustering of cognitive determinants of EBRBs (i.e., attitude, subjective norm, perceived behavioral control, and intention) and found that these cognitive determinants of EBRBs clustered even stronger than the behaviors themselves. Similarly, Rodenburg and colleagues reported clustering of children's food and activity preferences [72•]. Through this clustering, a positive change in the intrapersonal determinants of one behavior might induce a similar change in a related construct for another behavior. This principle of such synergistic effects could be utilized in preventive interventions [16].

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. World Health Organization: Childhood overweight and obesity on the rise. 2010; Available from: http://www.who.int/dietphysical activity/childhood/en/.

2. World Health Organization: Obesity: preventing and managing the global epidemic: report of a WHO consultation. In: WHO technical report series. Geneva: WHO; 2004.

3. Singh AS, Mulder C, Twisk JW, et al. Tracking of childhood overweight into adulthood: a systematic review of the literature. Obes Rev. 2008;9:474–88.

4. Kremers SP, Visscher TL, Seidell JC, et al. Cognitive determinants of energy balance-related behaviours: measurement issues. Sports Med. 2005;35:923–33.

5. Rennie KL, Johnson L, Jebb SA. Behavioural determinants of obesity. Best Pract Res Clin Endocrinol Metab. 2005;19:343–58.

6. Savage JS, Fisher JO, Birch L. Parental influence on eating behavior: conception to adolescence. J Law Med Ethics. 2007;35:22–34.

7. Reilly JJ, Jackson DM, Montgomery C, et al. Total energy expenditure and physical activity in young Scottish children: mixed longitudinal study. Lancet. 2004;363:211–2.

8. Kelder SH, Perry CL, Klepp KI, Lytle LL. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. Am J Public Health. 1994;84:1121–6.

9. Schuit AJ, van Loon AJ, Tijhuis M, Ocke M. Clustering of lifestyle risk factors in a general adult population. Prev Med. 2002;35:219–24.

10. • Kremers SP. Theory and practice in the study of influences on energy balance-related behaviors. Patient Educ Couns. 2010;79:291–8. *This article provides important guidelines for the study of energy balance-related behaviors, including clustering.*

11. Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev. 2004;62:177–203.

12. •• Gubbels JS, Kremers SP, Stafleu A, et al. Clustering of energy balance-related behaviors in 5-year-old children: lifestyle patterns and their longitudinal association with weight status development in early childhood. Int J Behav Nutr Phys Act. 2012;9:77. *This article is the first to include a broad range of eating routines instead of dietary intake items, as well as various types of activity behaviors in energy balance-related pattern analyses.*

13. Gubbels J, Kremers S, Goldbohm A, et al. Energy balance-related behavioral patterns in 5-year-old children and the longitudinal association with weight status development in early childhood. Public Health Nutr. 2012;15:1402–10.

14. Mikkila V, Rasanen L, Raitakari OT, et al. Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. Br J Nutr. 2005;93:923–31.

15. Northstone K, Emmett PM. Are dietary patterns stable throughout early and mid-childhood? A birth cohort study. Br J Nutr. 2008;100:1069–76.

16. Kremers SPJ, De Bruin GJ, Schaalma H, Brug J. Clustering of energy balance-related behaviours and their intrapersonal determinants. Psychol Health. 2004;19:595–606.

17. Kennedy ET, Ohls J, Carlson S, Fleming K. The Healthy Eating Index: design and applications. J Am Diet Assoc. 1995;95:1103–8.

18. Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index revised: a measurement instrument for populations. J Am Diet Assoc. 1999;99:697–704.

19. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. Am J Clin Nutr. 2002;76:1261–71.

20. Hu FB, Rimm SA, Smith-Warner SA, et al. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. Am J Clin Nutr. 1999;69:243–9.

21. Millen BE, Quatromoni PA, Copenhafer DL, et al. Validation of a dietary pattern approach for evaluating nutritional risk: the Framingham Nutrition Studies. J Am Diet Assoc. 2001;101:187–94.

22. Shin KO, Oh SY, Park HS. Empirically derived major dietary patterns and their associations with overweight in Korean preschool children. Br J Nutr. 2007;98:416–21.

23. Lioret S, Touvier M, Lafay L, et al. Dietary and physical activity patterns in French children are related to overweight and socioeconomic status. J Nutr. 2008;138:101–7.

24. Aranceta J, Perez-Rodrigo C, Ribas L, Serra-Majem L. Sociodemographic and lifestyle determinants of food patterns in Spanish children and adolescents: the enKid study. Eur J Clin Nutr. 2003;57:S40–4.

25. Stevens JP. Applied multivariate statistics for the social sciences. 2nd ed. Hinsdale: Erlbaum; 1992.

26. •• Jago R, Fox KR, Page AS, et al. Physical activity and sedentary behaviour typologies of 10–11 year olds. Int J Behav Nutr Phys Act. 2011;7:59. *This article is one of the few that includes various physical activity intensity levels in the study of activity patterns.*

27. Biddle SJ, Gorely T, Marshall SJ. Is television viewing a suitable marker of sedentary behavior in young people? Ann Behav Med. 2009;38:147–53.

28. Simons M, Bernaards C, Slinger J. Active gaming in Dutch adolescents: a descriptive study. Int J Behav Nutr Phys Act. 2012;9:118.

29. Saunders TJ, Prince SA, Tremblay MS. Clustering of children's activity behaviour: the use of self-report versus direct measures. Int J Behav Nutr Phys Act. 2011;8:48.

30. Jago R, Fox KR, Page AS, et al. Physical activity and sedentary behaviour typologies of 10–11 year olds—response to Saunders and colleagues. Int J Behav Nutr Phys Act. 2011;8:49.

31. Ruch N, Rumo M, Mader U. Recognition of activities in children by two uniaxial accelerometers in free-living conditions. Eur J Appl Physiol. 2011;111:1917–27.

32. Ngo J, Engleen A, Molag M, et al. A review of the use of information and communication technologies for dietary assessment. Br J Nutr. 2009;101:S102–12.

33. Ritchie LD, Spector P, Stevens MJ, et al. Dietary patterns in adolescence are related to adiposity in young adulthood in black and white females. J Nutr. 2007;137:399–406.

34. McNaughton SA, Ball K, Mishra GD, Crawford DA. Dietary patterns of adolescents and risk of obesity and hypertension. J Nutr. 2008;138:364–70.

35. Pryer JA, Rogers S. Dietary patterns among a national sample of British children aged 1 1/2–4 1/2 years. Public Health Nutr. 2009;12:957–66.

36. Gubbels JS, Kremers SP, Stafleu A, et al. Clustering of dietary intake and sedentary behavior in 2-year-old children. J Pediatr. 2009;155:194–8.

37. Yannakoulia M, Ntalla I, Papoutsakis C, et al. Consumption of vegetables, cooked meals, and eating dinner is negatively associated with overweight status in children. J Pediatr. 2011;157:815–20.

38. Craig LC, McNeill G, Macdiarmid JI, et al. Dietary patterns of school-age children in Scotland: association with socio-economic indicators, physical activity and obesity. Br J Nutr. 2010;103:319–34.

39. North K, Emmett P. Multivariate analysis of diet among three-year-old children and associations with socio-demographic characteristics. The Avon Longitudinal Study of Pregnancy and Childhood (ALSPAC) Study Team. Eur J Clin Nutr. 2000;54:73–80.

40. WHO/FAO Expert Consultation, Joint WHO/FAO Expert Consultation: Diet, nutrition and the prevention of chronic diseases. In: WHO Technical Report Series. WHO: Geneva; 2003.

41. Rasanen M, Lehtinen JC, Niinikoski H, et al. Dietary patterns and nutrient intakes of 7-year-old children taking part in an atherosclerosis prevention project in Finland. J Am Diet Assoc. 2002;102:518–24.

42. Striegel-Moore RH, Thompson D, Affenito SG, et al. Correlates of beverage intake in adolescent girls: the National Heart, Lung, and Blood Institute Growth and Health Study. J Pediatr. 2006;148:183–7.

43. Terre L, Drabman RS, Meydrech EF. Relationships among children's health-related behaviors: a multivariate, developmental perspective. Prev Med. 1990;19:134–46.

44. Thompson D, Jago R, Baranowski T, et al. Covariability in diet and physical activity in African-American girls. Obes Res. 2004;12:46S–54S.

45. Moreira P, Santos S, Padrao P, et al. Food patterns according to sociodemographics, physical activity, sleeping and obesity in Portuguese children. Int J Environ Res Public Health. 2010;7:1121–38.

46. Northstone K, Emmett P. Multivariate analysis of diet in children at four and seven years of age and associations with socio-demographic characteristics. Eur J Clin Nutr. 2005;59:751–60.

47. Kontogianni MD, Farmaki AE, Vidra N, et al. Associations between lifestyle patterns and body mass index in a sample of Greek children and adolescents. J Am Diet Assoc. 2011;110:215–21.

48. Knol LL, Haughton B, Fitzhugh E. Dietary patterns of young, low-income US children. J Am Diet Assoc. 2005;105:1765–73.

49. Yen LL, Chiu CJ, Wu WC, Pan LY. Aggregation of health behaviors among fourth graders in northern Taiwan. J Adolesc Health. 2006;39:435–42.

50. Nelson MC, Gordon-Larsen P, Adair LS, Popkin BM. Adolescent physical activity and sedentary behavior: patterning and long-term maintenance. Am J Prev Med. 2005;28:259–66.

51. Robinson TN, Hammer LD, Killen JD, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. Pediatrics. 1993;91:273–80.

52. Marshall SJ, Biddle SJ, Gorely T, et al. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. Int J Obes Relat Metab Disord. 2004;28:1238–46.

53. Tanasescu M, Ferris AM, Himmelgreen DA, et al. Biobehavioral factors are associated with obesity in Puerto Rican children. J Nutr. 2000;130:1734–42.

54. Pate RR, Health GW, Dowda M, Trost SG. Associations between physical activity and other health behaviors in a representative sample of US adolescents. Am J Public Health. 1996;86:1577–81.

55. Vilhjalmsson R, Thorlindsson T. Factors related to physical activity: a study of adolescents. Soc Sci Med. 1998;47:665–75.

56. Hesketh K, Crawford D, Salmon J. Children's television viewing and objectively measured physical activity: associations with family circumstance. Int J Behav Nutr Phys Act. 2006;3:36.

57. • Cameron AJ, Crawford DA, Salmon J, et al. Clustering of obesity-related risk behaviors in children and their mothers. Ann Epidemiol. 2011;21:95–102. *This study examines energy balance-related behavioral patterns in children as well as their mothers.*

58. • Seghers J, Rutten C. Clustering of multiple lifestyle behaviours and its relationship with weight status and cardiorespiratory fitness in a sample of Flemish 11- to 12-year-olds. Public Health Nutr. 2010;13:1838–46. *This study links lifestyle patterns to weight status as well as cardiorespiratory fitness.*

59. Van der Sluis ME, Lien N, Twisk JW, et al. Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents. Public Health Nutr. 2011;13:1716–21.

60. Sabbe D, De Bourdeaudhuij I, Legiest E, Maes L. A cluster-analytical approach towards physical activity and eating habits among 10-year-old children. Health Educ Res. 2008;23:753–62.

61. Halford JC, Boyland EJ, Hughes G, et al. Beyond-brand effect of television (TV) food advertisements/commercials on caloric intake and food choice of 5–7-year-old children. Appetite. 2007;49:263–7.

62. Coon KA, Goldberg J, Rogers BL, Tucker KL. Relationships between use of television during meals and children's food consumption patterns. Pediatrics. 2001;107:E7.

63. Temple JL, Giacomelli AM, Kent KM, et al. Television watching increases motivated responding for food and energy intake in children. Am J Clin Nutr. 2007;85:355–61.

64. Te Velde SJ, De Bourdeaudhuij I, Thorsdottir I, et al. Patterns in sedentary and exercise behaviors and associations with overweight

in 9–14-year-old boys and girls—a cross-sectional study. BMC Publ Health. 2007;7:16.

65. Golan M, Crow S. Parents are key players in the prevention and treatment of weight-related problems. Nutr Rev. 2004;62:39–50.

66. Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. Lancet. 2002;360:473–82.

67. Gubbels JS, Kremers SP, Stafleu A, et al. Association between parenting practices and children's dietary intake, activity behavior and development of body mass index: the KOALA Birth Cohort Study. Int J Behav Nutr Phys Act. 2011;8:18.

68. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: is it time to rethink the physical activity paradigm? Diabetes Res Clin Pract. 2011;93:292–4.

69. Helmink JHM, Kremers SPJ, van Brussel-Visser FN, de Vries NK. Sitting time and body mass index in diabetics and pre-diabetics

willing to participate in a lifestyle intervention. Int J Environ Res Public Health. 2011;9:3747–58.

70. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a Portuguese sample of men: results from the Azorean Physical Activity and Health Study (APAHS). Int J Environ Res Public Health. 2011;7(4):1500–7.

71. Gubbels JS, Kremers SPJ, Stafleu A, et al. Diet-related restrictive parenting practices. Impact on dietary intake of 2-year-old children and interactions with child characteristics. Appetite. 2009;52:423–9.

72. • Rodenburg G, Oenema A, Pasma M, et al. Clustering of food and activity preferences in primary school children. Appetite. 2013;60:123–32. *This article is one of the few presenting data on clustering of determinants of energy balance-related behaviors (in this case: food and activity preferences).*