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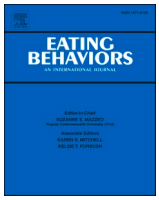

Associations between parental and pre-adolescents' physical activity and diet quality: The role of parental child care involvement and child's sex

Helle Larsen [a], Roel C.J. Hermans [b], Sara Kayabal [c], Carry M. Renders [d], Tanja G.M. Vrijkotte [c,*]

[a] Department of Psychology, Developmental Psychology, University of Amsterdam, Postbus 15916, 1001 NK Amsterdam, the Netherlands
[b] NUTRIM School of Nutrition and Translational Research in Metabolism, Maastricht University, PO Box 616, 6200 MD, Maastricht, the Netherlands
[c] Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Amsterdam UMC, University of Amsterdam, Postbox 22660, 1100 DD Amsterdam, the Netherlands
[d] Department of Health Sciences, Faculty of Science, Vrije Universiteit Amsterdam, Amsterdam Public Health Research Institute, the Netherlands

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ABSTRACT

Background: Research has demonstrated the importance of the family environment in the eating and activity levels of offspring. We examined the cross-sectional associations between moderate-to-vigorous physical activity (MVPA) and diet quality of parents and the MVPA and diet quality of pre-adolescents. Interactions were tested to assess whether the child's sex and the parental level of involvement in daily child care moderated these associations.

Methods: Data from 2467 pre-adolescents (age 11.5 ± 0.2 years; collected in 2015–2016) and their parents or caregivers from a large-scale prospective birth cohort study in Amsterdam (ABCD-study) was used. Parents and pre-adolescents individually reported their diet quality and physical activity. Child care involvement was assessed using the Caregiver Child Interaction Scale. With hierarchical linear regression analyses, we assessed the independent contribution of fathers and mothers.

Results: An association between mother-child MVPA was found (β = 0.013; 95 % CI: 0.006;0.021). The association between father-child MVPA was only significant for highly involved fathers (β = 0.014; 95 % CI: 0.004;0.023). The child's sex did not change these MVPA associations. Regarding diet quality, associations were found between mother-child diet quality score (DQS) (β = 0.254; 95 % CI: 0.192;0.316) and father-child DQS, with stronger associations between fathers and sons (β = 0.234; 95 % CI: 0.169;0.298) than between fathers and daughters (β = 0.114; 95 % CI: 0.047;0.181). Parental levels of involvement did not change these associations.

Conclusion: These findings demonstrate that both parental behaviours represent an important factor in physical activity and diet quality in pre-adolescents in a sex-specific manner. As such, it is essential to include both parents in research to obtain the necessary insights for developing effective interventions to promote children's healthy eating and physical activity behaviours.

1. Introduction

It has been widely acknowledged that regular physical activity (PA), reduced sedentary activity, and healthy nutritional habits are associated with improved health outcomes, such as physical fitness and cardiometabolic health especially in adolescents (Bull et al., 2020; Cecchini et al., 2010; Janssen & Leblanc, 2010; Lobstein et al., 2015; Norris et al., 2022). These energy balance-related behaviours also play an important role in preventing non-communicable diseases such as diabetes, heart disease, stroke and cancer (Balbus et al., 2013). Childhood and pre-adolescence are crucial life phases for establishing lifelong healthy energy balance-related behaviours (Craigie, Lake, Kelly, Adamson, & Mathers, 2011; Lobstein et al., 2015). The period of adolescence represents a distinctive phase of life characterized by swift and profound

Abbreviations: ABCD, Amsterdam Born Children and their Development; BMI, body mass index; CCIS, Caregiver Child Interaction Scale; DQS, dietary quality score; MVPA, moderate-to-vigorous physical activity; PA, physical activity; SSBs, sugar-sweetened beverages.

* Corresponding author at: Department of Public and Occupational Health, Amsterdam UMC, University of Amsterdam, PO Box 22660, 1100 DD Amsterdam, the Netherlands.
E-mail addresses: h.larsen@uva.nl (H. Larsen), info@leefstijllab.nl (R.C.J. Hermans), carry.renders@vu.nl (C.M. Renders), t.vrijkotte@amsterdamumc.nl (T.G.M. Vrijkotte).

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biological and social transformations. Important developmental tasks in adolescence is increased autonomy and desire to feel respected, and these factors have been found to have a connection with food choices and unhealthy snacking (Bassett, Chapman, & Beagan, 2008; Neufeld et al., 2022; Yeager, Dahl, & Dweck, 2018).

The WHO Guidelines 2020 on physical activity and sedentary behaviour recommend that children and adolescents (aged 5–17 years) spend at least an average of 60 min per day on moderate-to-vigorous physical activity (MVPA) across the week (Bull et al., 2020). Furthermore, these guidelines recommended that children and adolescents limit the amount of sedentary time, mainly recreational screen time (Bull et al., 2020). Moreover, national food-based dietary guidelines recommend a dietary intake pattern that includes a variety of fruit and vegetables, whole grains, and protein foods, and reducing the intake of free sugars to <10 % of the total energy intake (Cecchini et al., 2010; Lobstein et al., 2015). However, most youths do not meet these recommendations. They show high levels of sedentary behaviours (e.g., watching television, computer use), high intakes of energy-dense, low-nutrition foods (e.g., sugar-sweetened beverages, energy-dense snacks), low intakes of nutrition-rich foods (e.g., fruits and vegetables), and low levels of physical activity (Case & Paxson, 2002; Krijger et al., 2021; Yee, Lwin, & Ho, 2017).

Parents play a fundamental role in establishing and supporting their children's healthy lifestyle behaviours (Case & Paxson, 2002; Niermann, Gerards, & Kremers, 2018). Parents' physical activity, for example, may directly influence their child's physical activity — often referred to as parental modelling (Case & Paxson, 2002). The relationship between parental and child physical activity has been examined extensively. Overall, evidence for an association between parents' and child's PA exists, but the observed effects have been weak and may differ between children and adolescents and boys and girls (Edwardson & Gorely, 2010; Yao & Rhodes, 2015). Moreover, many studies have been published on the relationship between parental modelling and children's dietary intake. Although these studies indicate a strong relationship between the dietary intakes of parents and their children, they also show that differences exist between older and younger children and that the strength of the relationship vary across food groups (McClain, Chappuis, Nguyen-Rodriguez, Yaroch, & Spruijt-Metz, 2009; Pearson, Biddle, & Gorely, 2009; van der Horst et al., 2007; Yee et al., 2017). Based on the systematic review and meta-analysis of Yee et al. (2017), the relationship between parental modelling and child behaviours (i.e. food consumption) seem to be homogenous and significant, as consistent links were found between parental modelling and both desirable and undesirable food consumption across ages (Yee et al., 2017). The systematic reviews of van der Horst et al. (2007), Pearson et al. (2009), and McClain et al. (2009) also did not find differences in parental modelling between children and adolescents (McClain et al., 2009; Pearson et al., 2009; van der Horst et al., 2007). We therefore expect parental modelling to also play a role in child behaviours related to diet and MVPA.

While the role of parental modelling in children's energy balance-related behaviour has been studied extensively, research in this area has traditionally focused on mothers. This focus may not only be the result of traditional views of parental roles, in which mothers have been considered the primary family caretakers, but also because of the low response rates of fathers compared to mothers in studies on this topic (Morgan et al., 2017; Rahill, Kennedy, & Kearney, 2020; Walsh et al., 2017). Nevertheless, it is known that parenting practices, such as parental modelling, may differ between mothers and fathers. Some studies, for example, demonstrated that the father's PA was more often associated with the child's PA than the mother's PA (Edwardson & Gorely, 2010; Lloyd, Lubans, Plotnikoff, Collins, & Morgan, 2014), while other studies only found an association between PA levels of mothers and daughters (Jago, Fox, Page, Brockman, & Thompson, 2010; Tanaka, Okuda, Tanaka, Inoue, & Tanaka, 2018). Similarly, studies found that although fathers are involved in food parenting, this is often at a lower level than mothers (Davison, Haines, Garcia, Douglas, & McBride, 2020; Panter-Brick et al., 2014). Furthermore, they demonstrated few consistent mother-father differences in food-related parenting (Davison et al., 2020; Panter-Brick et al., 2014). However, only a few studies have assessed the independent parental contributions by adjusting the associations for mothers versus fathers relative to each other (Davison et al., 2020; Sleddens, Gerards, Thijs, de Vries, & Kremers, 2011; Deslippe, O'Connor, Brussoni, & Mâsse, 2022). As a result, the relative contributions of maternal and paternal behaviour to children's behaviour remain mostly unclear and need further research (Larsen et al., 2015). Similarly, little is known about the relative contribution of each parent to sons and daughters (Morgan et al., 2017).

An important construct to consider in this context is parental involvement or engagement in daily child care. Involvement is defined as direct contact with the child through caretaking and shared activities, such as studying, taking part in sports, or family leisure activities (McWayne, Downer, Campos, & Harris, 2013). Research has shown the beneficial effects of engaged fathers and mothers on all areas of child development (Edwardson & Gorely, 2010; McWayne et al., 2013; Niermann et al., 2018; Rahill et al., 2020), including diet or physical activity interventions in the ages up to 12 years old (Tomayko et al., 2021). So far, it is unknown if associations between the physical activity of parents and children and their diets may differ between parents with various levels of involvement. Engaged parents might give the child more opportunities to learn or model parental behaviour. This parental engagement might positively affect the child if the parent is a role model for healthy energy balance-related behaviour but negatively affect the child regarding unhealthy modelling behaviour.

The present study investigated the independent roles of mothers and fathers in their child's PA and diet quality within families. The primary aim was to gain more insight into mothers' and fathers' potential relative contributions to pre-adolescents' MVPA and diet quality. In addition, this study explored whether the child's sex and parental level of involvement in daily child care moderated these associations. Understanding the relative caregiving roles of individual parents in developing healthy lifestyle behaviour in their children might help develop more effective family-centred interventions to benefit the health and well-being of children and adolescents.

2. Methods

2.1. Study design and population

Child and parental self-reported data were obtained from the ABCD-study. This population-based cohort study in Amsterdam, which commenced in 2003, aims to investigate to what extent children's early-life conditions may explain their development and health later in life (van Eijsden, Vrijkotte, Gemke, & van der Wal, 2011). In 2015 and 2016, the children and parents who still participated in the ABCD-study (N = 5645) were invited when the children were 11–12 years old. Of the approached 5645 families, 3254 families (response rate 57.6 %) returned the questionnaire. Parent-child pairs were excluded when information on PA or dietary intake was missing (N = 787). This selection resulted in 2467 families, of whom 2167 mother-child pairs and 1954 father-child pairs with complete MVPA data, and 2384 mother-child pairs and 2147 father-child pairs with complete diet quality score (DQS) data (Fig. 1). Seventeen percent (n = 425) of the families were single parent families.

Family members (children, fathers, mothers, or caregivers) were asked to complete a questionnaire individually. The current study assessed the levels of physical activity, diet quality, and parental child care involvement. For this study purpose, we included the father-child and mother-child relationships and no other family members. The Central Committee on Research Involving Human Subjects in the Netherlands and the medical ethics review committees of the participating hospitals approved the protocol of the ABCD-study. Written informed consent of all participants was obtained.

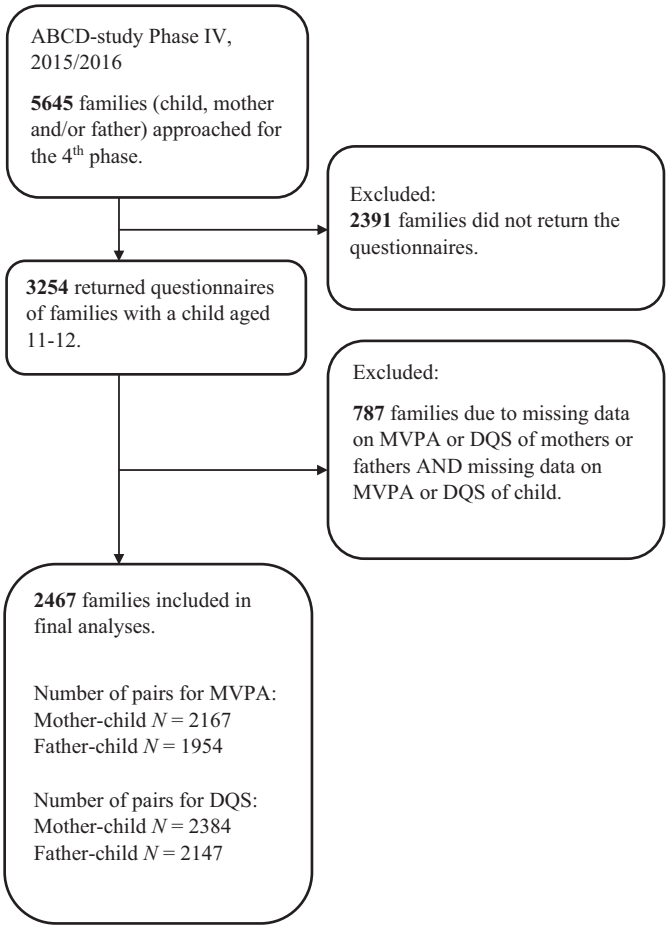

Fig. 1. Flowchart summarising the study population and exclusion criteria.

2.2. Measures

2.2.1. MVPA of parents and children

Parental MVPA was based on the question: '*How many minutes on average do you sport during the week?*' and defined as minutes per week. The children's MVPA was based on the question: '*Do you practice sport? If yes, what kind of sport and how many hours a week do you practice it, including training and competitions?*' Walking and cycling to school or work were excluded from MVPA according to the definition used by the WHO (Bull et al., 2020; Health Council of the Netherlands, 2017). In the case of more than one organised sport, the same question was repeated. Based on these questions, a weekly metabolic equivalents (METs) score was calculated for children following the method described by the WHO (World Health Organization, 2020).

2.2.2. DQS of parents and children

To assess the quality of the diet of parents and children, they filled in questions on their food intake that we developed based on existing questionnaires (de Vries, Bakker, van Overbeek, Boer, & Hopman-Rock, 2005; Singh et al., 2006). Specifically, the DQS of parents and pre-adolescents was assessed using a questionnaire concerning the dietary intake of four food groups: fruits (excluding juice), vegetables, snacks (e.g., biscuits, candy, chocolate, crisps), and sugar-sweetened beverages (SSBs such as fruit juice and soft drinks). By including these food groups, we were able to indicate a more healthy or a more unhealthy food intake. For each food group, the average daily intake was calculated and divided into quartiles, with the lowest quartile rated as 1 and the highest as 4 for fruits and vegetables. For snacks and SSBs, the scores were reversed because high intakes are unhealthy. Cut-off values of the quartiles for each food component can be find in Supplementary Material (Table S7). The DQS was calculated by combining the scores of the individual food groups (range 4–16). A total of 4 indicated the unhealthiest diet quality intake and 16 the healthiest diet quality intake.

2.2.3. Parental child caregiving involvement

This was assessed using an adapted version of the Child Caregiving Involvement Scale (CCIS) (Wood & Repetti, 2004). This scale measures the parents' perceived level of responsibility for specific daily activities, including those relating to health and safety, routines/time spent, physical attention, discipline, language development, learning opportunities, and involvement with children's activities. In this study, involvement was based on eight questions, e.g., '*Do you help your child with their homework?*' or '*Do you take your child to the sports complex?*'. We removed the two items 'Teaching a child skills and things about the world (outside of school)' because it was too general and 'Making child-care arrangements' because it was not relevant for 11–12 years old. A 5-point Likert scale was used, in which a score of one indicated no to little responsibility (0 < 10 %), two indicated 10 < 40 %, three indicated 40 < 60 %, four indicated 60 < 90 %, and five indicated having almost all the responsibility (90–100 %). In the current sample, Cronbach's alpha was 0.84 for the fathers' scale and 0.83 for the mothers' scale. Mean CCIS scores were calculated separately for mothers and fathers.

2.2.4. Covariates

On individual and family levels, demographic and socioeconomic covariates were obtained from parents and children (Yılmaz, Renders, Nicolaou, & Vrijkotte, 2019). These covariates included age (years), body mass index (BMI) based on measured height and weight (Krijger et al., 2021), which were assessed during a health check and with linked data from the Youth Health Care (Vrijkotte, Varkevisser, van Schalkwijk, & Hartman, 2020), ethnicity based on the mother and her mother's country of birth and categorised into 'Dutch', 'other Western' and 'other Non-Western' ethnicity, and the child's sexual maturation. The child's sexual maturation was assessed using the Tanner scale (Petersen, Crockett, Richards, & Boxer, 1988) scored by the mother, and categorised into 'puberty not started' and 'puberty started'. Furthermore, the parental educational level covariate was categorised into low (primary school, technical secondary education, or lower vocational secondary education), moderate (a degree in higher vocational secondary education, academic secondary education, or intermediate vocational education) or high (a degree in higher vocational education or university). Other covariates were smoking habits (yes or no), employment status (unemployed, working ≤24 h, working >24 and <32 h, and working ≥32 h), self-perceived family financial status (inadequate, adequate, and more than adequate to live), and the number of siblings. BMI categories were calculated according to age and sex-specific cut-off values using the WHO guidelines (World Health Organization, 2006).

2.3. Statistical analysis

The representativeness of the study population was explored by comparing the baseline characteristics of all included children (N = 2467) to those who were eligible but were not included (N = 3178) by independent sample t-testing and chi-square testing. An ANOVA was performed to assess the mean differences of the child's MVPA and DQS for measured baseline characteristics.

Hierarchical linear regression analyses were performed to assess the associations between parent-child MVPA and parent-child DQS. Four separate analyses were performed: mother-child MVPA, mother-child DQS, father-child MVPA, and father-child DQS, respectively. In the mother-child MVPA analysis, the first crude model included the mother's MVPA. Model 2 was further adjusted for the following a priori-stated confounders: child's sex, age, and pubertal stage, mother's age, BMI, education, smoking status, and employment status, and the familial factors of self-perceived financial status and number of siblings. In

model 3, the analysis was adjusted for the fathers' MVPA. The same strategy was applied to determine the father-child MVPA association. Moreover, the same hierarchical procedure as for MVPA was followed to determine the association between mother-child DQS and father-child DQS.

To examine differences between daughters and sons in the parent-child MVPA and DQS associations, the effect modification by sex was tested by creating an interaction term between the child's sex and parents' MVPA/DQS and adding it to model 3. Moreover, an interaction term between parents' child care involvement and MVPA/DQS was tested in model 3. If the added interaction coefficient had a *p*-value of <0.05, effect modification was assumed, and results were stratified accordingly. As child care involvement was measured on a continuous scale, a statistically significant interaction was further examined using Hayes' PROCESS macro version 3 for SPSS to estimate the cut-off values of the interaction effect (Hayes, 2013). Analyses were then stratified based on these cut-off values.

In addition to previous analyses, a sensitivity analysis was conducted to examine if any differences compared to the total dataset exist for the associations of parent-child MVPA and parent-child DQS when only children living with two parents (two-parent family; $N = 2042$) were included. A second sensitivity analysis was performed to see if the results differed from those obtained from the total dataset when missing values on covariates were imputed. Multiple imputation by chained equation was conducted for 20 datasets. The highest percentages of missing values were found for the age (24.3 %), BMI (13.7 %), MVPA (13.5 %), and involvement in daily child care (12.8 %) of fathers.

A *p*-value of <0.05 was considered statistically significant for all analyses. Unadjusted and adjusted regression coefficients were provided with 95 % confidence intervals (95 % CI). All analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., 2017).

3. Results

3.1. Non-response

Compared to the non-response group, mothers in the included group were more often of Dutch origin (74.7 % versus 51.1 %) and older at the start of their pregnancy (32.4 ± 4.2 versus 30.2 ± 5.4 years). Moreover, they smoked less during pregnancy (93.0 % versus 88.0 %), were more highly educated (10.5 ± 3.3 versus 8.2 ± 4.0 years of education after primary school), more often employed (86.5 % versus 68.2 %), and more often nulliparous during the pregnancy (57.9 % versus 54.8 %; Supplementary Table S1).

3.2. Study population

The mean consumption of fruit and vegetables was comparable between parents and children. However, the consumption of snacks and SSBs was higher among children than parents. The mean DQS was comparable for children and parents (Table 1).

MVPA was significantly higher in boys and children who did not yet enter puberty, had non-smoking parents, had more highly educated parents, had mothers who worked >32 h/week, had mothers who were less involved in child care, and had families with a higher financial status. Compared to children of Dutch origin, children of other Western origins scored higher on DQS, while children of other non-Western origins scored lower on DQS. Also, children from an overweight mother or father had a lower DQS than children from mothers or fathers of average weight. Children from non-smoking mothers had a higher DQS than those from smoking mothers (Table 2). Mother, father and child MVPA and DQS correlated significantly (Supplementary Table S2).

3.3. Moderate-to-vigorous physical activity

The MVPA of mothers was positively associated with the MVPA of children after adjustments for confounders in model 2 (Table 3). After adding the MVPA of fathers in model 3, the positive association slightly decreased but remained significant, which shows the independent contribution of mothers' MVPA to the MVPA of children. No significant effect modifications were found for the child's sex or child care involvement of mothers. The same results were found for father-child MVPA. After adding the MVPA of mothers in model 3, the positive association slightly decreased but remained statistically significant. The involvement of fathers proved to be a statistically significant effect modifier. The interaction was observed at the following three mean CCIS scores: 2.45 (low), 3.08 (moderate) and 3.71 (high), as calculated using Hayes PROCESS. The father-child MVPA association was stronger for fathers with high child care involvement. After adding the MPVA of mothers, the father-child MVPA association was only significant for those with a high level of involvement. Effect modification by sex was not observed for the association between father-child MVPA.

3.4. Diet quality score

The DQS of mothers was significantly positively associated with the DQS of children after adjustment for confounders in model 2 (Table 4). This association slightly decreased after adding the DQS of fathers. No significant effect modification by the child's sex or child care involvement of mothers was found. Also, a significantly positive father-child DQS association was found after adjusting for the DQS of mothers in model 3. The child's sex was an effect modifier in this association. The positive father-son DQS association was stronger than for father-daughter DQS. The interaction between fathers' child care involvement and DQS was not significant.

Table 1
Mean and standard deviations of BMI, MVPA, diet, DQS, and parental involvement for the children, mothers, and fathers included in this study.

	N	Son M ± SD	*N*	Daughter M ± SD	*N*	Mother M ± SD	*N*	Father M ± SD
Age	1218	11.5 ± 0.2	1249	11.5 ± 0.3	2420	44.8 ± 4.1	1868	47.1 ± 5.3
BMI (kg/m^2)	943	17.0 ± 2.5	961	16.9 ± 2.7	2309	23.6 ± 3.9	2129	25.0 ± 3.2
MVPA[a]	1123	32.4 ± 5.2	2235	24.4 ± 13.8	2384	96.6 ± 3.6	2133	112.6 ± 111.9
Dietary intake								
Fruits (servings/day)	1202	2.3 ± 1.2	1236	2.3 ± 1.1	2378	2.1 ± 3.1	2139	1.8 ± 2.9
Vegetables (servings/day)	1202	3.0 ± 1.2	1236	3.0 ± 1.1	2381	3.3 ± 5.0	2137	3.1 ± 2.3
Snacks (servings/day)	1213	3.6 ± 1.4	1243	3.9 ± 1.8	2378	1.8 ± 1.5	2114	1.6 ± 1.6
SSBs (glasses/day)	1206	4.1 ± 1.9	1229	3.6 ± 1.4	2372	1.0 ± 1.6	2142	1.4 ± 2.2
DQS[b]	1213	9.6 ± 2.5	1243	9.6 ± 2.4	2394	10.6 ± 2.4	2154	10.5 ± 2.4
Child care involvement	–	–	–	–	2397	3.7 ± 0.7	2151	3.1 ± 0.7

Abbreviations: BMI: body mass index, MVPA: moderate-to-vigorous physical, DQS: diet quality score, SSBs: sugar-sweetened beverages.
The number of participants slightly differs for each variable due to missing data.
[a] MVPA in metabolic equivalents (METs/week) for children and minutes/week for parents.
[b] DQS is a total score of the four food component categories, ranging between 4 and 16.

Table 2
Means and standard deviations of the children's MVPA and DQS arranged by the characteristics of children, mothers, and fathers.

	n	MVPA of child[a] Mean ± SD	*n*	DQS of child[b] Mean ± SD
Sex of child				
Male	1123	32.4 ± 15.2***	1213	9.6 ± 2.5
Female	1112	24.4 ± 13.8	1243	9.6 ± 2.4
Age of child				
≤11.5 (years)	1237	28.9 ± 15.0	1353	9.6 ± 0.1
>11.5 (years)	998	27.9 ± 15.2	1103	9.5 ± 0.1
Puberty started				
No	2083	28.6 ± 15.1*	2267	9.6 ± 2.4
Yes	110	25.5 ± 15.2	140	9.6 ± 2.5
BMI of child				
Underweight	110	27.5 ± 16.0	120	9.4 ± 2.3
Normal weight (*reference*)	1401	29.0 ± 14.7	1495	9.6 ± 2.4
Overweight	212	26.5 ± 16.6	250	9.5 ± 2.6
Ethnicity of child				
Dutch (*reference*)	1736	28.7 ± 14.8	1835	9.6 ± 2.4
Other Western	277	27.1 ± 15.3	302	10.0 ± 2.5*
Other Non-Western	222	27.9 ± 17.0	319	9.1 ± 2.5**
Age of mother (years)				
≤45	1061	28.7 ± 15.1	1196	9.7 ± 2.4**
45–50 (*reference*)	924	28.2 ± 15.1	982	9.4 ± 2.5
>50	207	28.8 ± 15.0	229	9.8 ± 2.4
Age of father (years)				
≤45	642	28.4 ± 14.8	689	9.5 ± 2.5
45–50 (*reference*)	660	29.2 ± 14.6	697	9.6 ± 2.4
>50	425	29.1 ± 14.9	472	9.7 ± 2.3
BMI of mother				
Underweight	47	28.9 ± 16.9	52	10.0 ± 2.4
Normal weight (*reference*)	1527	28.9 ± 14.9	1640	9.7 ± 2.5
Overweight	388	27.3 ± 14.8	436	9.2 ± 2.4***
Obesity	118	26.3 ± 16.2	143	9.0 ± 2.5**
BMI of father				
Underweight	9	32.3 ± 15.6	10	9.1 ± 2.7
Normal weight (*reference*)	1046	29.1 ± 15.1	1108	9.7 ± 2.4
Overweight	772	28.6 ± 14.8	854	9.4 ± 2.4*
Obesity	95	26.0 ± 15.3	112	9.6 ± 2.4
Smoking status of mother				
No	1918	28.7 ± 15.0*	2093	9.6 ± 2.4**
Yes	263	26.4 ± 15.6	300	9.1 ± 2.5
Smoking status of father				
No	1610	29.2 ± 15.0**	1735	9.6 ± 2.4
Yes	362	26.8 ± 14.8	410	9.4 ± 2.5
Education level of mother				
Low	30	30.1 ± 17.6	40	8.8 ± 2.5*
Medium	437	25.3 ± 15.0***	538	8.7 ± 2.5***
High (*reference*)	1724	29.2 ± 15.0	1826	9.8 ± 2.4
Education level of father				
Low	22	25.1 ± 18.8	35	8.8 ± 2.3*
Medium	465	26.0 ± 14.4***	545	9.1 ± 2.5***
High (*reference*)	1489	29.7 ± 15.0	1570	9.8 ± 2.4
Employment status of mother				
Unemployed	303	26.3 ± 14.5***	370	9.3 ± 2.6*
≤24 h	276	27.5 ± 16.2*	305	9.6 ± 2.5
24 < 32 h	618	27.0 ± 14.8***	669	9.4 ± 2.4**
≥32 h (*reference*)	970	30.2 ± 14.7	1035	9.8 ± 2.4
Employment status of father				
Unemployed	130	27.4 ± 16.9	166	9.4 ± 2.4
≤24 h	67	29.1 ± 14.5	79	10.1 ± 2.4
24 < 32 h	124	29.3 ± 17.2	136	9.8 ± 2.3
≥32 h (*reference*)	1637	28.8 ± 14.7	1748	9.6 ± 2.4
MVPA recommendation of mother[c]				
<150 min/week	1615	27.7 ± 14.9***	1789	9.5 ± 2.5
≥150 min/week	552	31.1 ± 15.4	585	9.7 ± 2.4
MVPA recommendation of father[c]				
<150 min/week	1297	27.9 ± 14.8***	1439	9.6 ± 2.4
≥150 min/week	657	30.7 ± 15.1	686	9.7 ± 2.5
Child care involvement of mother				
<60 %	405	31.3 ± 16.0***	447	9.7 ± 2.4
≥60 %	1770	27.9 ± 14.8	1940	9.5 ± 2.4
Child care involvement of father				
<60 %	1133	28.3 ± 14.9	1208	9.6 ± 2.4
≥60 %	841	29.5 ± 15.1	936	9.6 ± 2.5
Perceived family financial status				
Inadequate	217	26.7 ± 14.8*	262	9.5 ± 2.6
Adequate	642	26.7 ± 15.4***	753	9.5 ± 2.5
More than adequate (*reference*)	1374	29.6 ± 14.8	1439	9.6 ± 2.4

Abbreviations: BMI: body mass index, MVPA: moderate-to-vigorous physical, DQS: diet quality score.
The number of participants slightly differs for each variable due to missing data.
[a] MVPA was measured in metabolic equivalents (METs/week) for children.
[b] DQS is a total score of the four food component categories, ranging between 4 and 16.
[c] The WHO recommends at least 150 min/week of moderate-to-vigorous physical activity for parents (Bull et al., 2020).
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

3.5. Sensitivity analyses

When including only children living with two parents, the results were essentially the same as the original analyses (Supplementary Tables S3–S4). The effect modifications by the child's sex and father's involvement in the father-child MVPA and DQS relationships were also confirmed. Moreover, in the sensitivity analyses after multiple imputation, the child's sex moderated the relation between mother-child DQS ($p = 0.038$). The positive mother-son DQS association was stronger than the mother-daughter DQS (Supplementary Tables S5–S6).

4. Discussion

The findings of this study indicate that MVPA and dietary intake of mothers and fathers are independently associated with that of their children. For MVPA, these associations did not differ for sons and daughters or mothers with varying levels of involvement. However, the father-child MVPA association was positive and only significant for fathers with high involvement in daily child care, after adding MPVA of mothers into the model. Mothers' dietary intake was more strongly associated with their children's intake than fathers' dietary intake, although they still have an independent contribution. This contribution was stronger for their sons than their daughters. The parental level of involvement did not influence the association between the parental and children's dietary intake.

This study's results regarding the positive association between parent-child MVPA are consistent with several systematic reviews and meta-analyses (Edwardson & Gorely, 2010; Jago et al., 2010; Yao & Rhodes, 2015) and extend these findings by showing that fathers and mothers independently contribute to their child's behaviour. Parental attitudes about PA and their PA levels seem to be important determinants of children's PA levels (Bianchi & Milkie, 2010). Thus, an important explanation for the parent-child PA association is that physically active parents may stimulate and facilitate their children more to

Table 3
Results of regression analyses for the parent-child MVPA associations.

	Mother-child MVPA ($N = 1798$)			Father-child MVPA ($N = 1632$)		
	R^2	β	95 % CI	R^2	β	95 % CI
Model 1[a]	0.015	0.020***	0.013;0.027	0.013	0.015***	0.004;0.022
Model 2[b]	0.115	0.016***	0.009;0.023	0.104	0.013***	0.007;0.020
Model 3[c]	0.122	0.013***	0.006;0.021	0.100	0.011**	0.005;0.018

	Father-child MVPA stratified by the level of child care involvement								
	Low ($N = 191$)			Mid ($N = 751$)			High ($N = 686$)		
	R^2	β	95 % CI	R^2	β	95 % CI	R^2	β	95 % CI
Model 1[a]	0.001	0.004	−0.016;0.023	0.008	0.013*	0.003;0.024	0.020	0.018***	0.008;0.027
Model 2[b]	0.158	0.002	−0.017;0.022	0.106	0.011*	0.001;0.021	0.116	0.015**	0.006;0.024
Model 3[c]	0.162	0.000	−0.020;0.020	0.117	0.008	−0.003;0.018	0.120	0.014**	0.004;0.023

Abbreviations: BMI: body mass index, MVPA: moderate-to-vigorous physical.
Note: two-parent and single-parent families were included.
[a] Model 1: Crude model of the association between mother-child MVPA and father-child MVPA.
[b] Model 2: Model 1 + adjustment for the child's sex, age, pubertal stage, and for maternal covariates in the analysis of mothers and paternal covariates in the analysis of fathers. Covariates are parental age, BMI, smoking status, education level, employment status, and ethnicity, number of siblings, and perceived financial status.
[c] Model 3: Model 2 + adjustment for paternal MVPA for mother-child analyses and adjustment for maternal MVPA for father-child analyses.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 4
Results of regression analyses for the parent-child DQS associations.

	Mother-child DQS ($N = 1958$)			Father-child DQS ($N = 1762$)		
	R^2	β	95 % CI	R^2	β	95 % CI
Model 1[a]	0.092	0.305***	0.262, 0.347	0.061	0.251***	0.205, 0.297
Model 2[b]	0.131	0.268***	0.225, 0.311	0.094	0.237***	0.190, 0.283
Model 3[c]	0.153	0.230***	0.187, 0.274	0.150	0.176***	0.130, 0.223

	Father-child DQS associations stratified by child's sex					
	Father-son DQS ($N = 881$)			Father-daughter DQS ($N = 881$)		
	R^2	β	95 % CI	R^2	β	95 % CI
Model 1[a]	0.092	0.308***	0.244;0.372	0.035	0.190***	0.123;0.256
Model 2[b]	0.129	0.302***	0.237;0.367	0.080	0.166***	0.099;0.233
Model 3[c]	0.150	0.234***	0.169;0.298	0.122	0.114***	0.047;0.181

Abbreviations: BMI: body mass index, DQS: diet quality score.
Note: two-parent and single-parent families were included.
[a] Model 1: Crude model of the association between mother-child DQS and father-child DQS.
[b] Model 2: Model 1 + adjustment for the child's sex, age, pubertal stage, and for maternal covariates in the analysis of mothers and paternal covariates in the analysis of fathers. Covariates are parental age, BMI, smoking status, education level, employment status, and ethnicity, number of siblings, and perceived financial status.
[c] Model 3: Model 2 + adjustment for paternal DQS for mother-child analyses and adjustment for maternal DQS for father-child analyses.
*** $p < 0.001$.

be physically active than parents who are not physically active. Parents stimulate and facilitate their children's PA by enrolling them in sports activities and providing logistical support. Comparable associations were found for boys and girls, although some studies showed stronger associations between parent-son MVPA (Brouwer et al., 2018; Edwardson & Gorely, 2010; Lloyd et al., 2014; Yang, Telama, & Laakso, 1996) while others did not (Isgor, Powell, & Wang, 2013). This study showed positive parent-child dietary intake associations, with stronger associations for mothers than fathers. Several prior studies reached the same conclusion (Fisk et al., 2011; Vepsäläinen et al., 2018; Yee et al., 2017). Mothers still spend more time on their children's dietary practices than fathers, although their increasing employment rates (Bianchi & Milkie, 2010; Raley, Bianchi, & Wang, 2012) may explain that the role of fathers is also significant. When their wives are employed, fathers engage in more care of their children and participate more in routine care when their wives contribute financially to the household (Raley et al., 2012). We also found a stronger father-son than father-daughter dietary intake association. This could be explained by fathers 'investment that seem to be higher in families with sons and that fathers spent more time with sons than with daughters (Raley & Bianchi, 2006). Consequently, fathers may influence their son's dietary intake more than their daughter's. Moreover, sons may also see their fathers more than their mothers as role models regarding ideas about and intake of healthy or unhealthy food. Nevertheless, the parent-child dietary intake associations found in the present and previous studies range from weak to moderate.

No other study examined the moderating effect of parental levels of involvement in daily child care associated with parental and children's energy balance-related behaviour. In this study, we consider involvement not only by being physically active and participating in leisure activities but, for example, also by helping with homework and health care for the child. We found similar effect sizes for mother-child MVPA associations in general and father-child MVPA associations for fathers

with high levels of involvement in daily child care. The level of involvement in child care was higher for mothers than fathers, which confirms results showing that mothers remain responsible for most of the household and child care (Craig, Powell, & Smyth, 2014; Yogman & Garfield, 2016). Parents serve as role models; therefore, their influence and interaction with their children may be one of the most important modifiable factors in promoting healthy behaviour in children. However, other parental practices may also be important. A systematic review revealed that mothers are perceived as more accepting, responsive, and supportive compared to fathers. Additionally, mothers are also seen as more behaviourally controlling, demanding, and granting autonomy (Yaffe, 2020). These could be relevant practices to increase physical activity and healthy diet. Especially, in (pre-)adolescence, including adolescents in a bottom-up approach and ensuring autonomy granting is crucial (Neufeld et al., 2022; Yeager et al., 2018). The interpretation of this study's findings is that fathers are equally important when they are equally involved in daily child care. This interpretation supports the idea that the family environment plays a fundamental role in establishing and supporting children's healthy lifestyle behaviours. Research on parenting relating to food and physical activity has primarily focused on mothers, and much less is known about the impact of fathers on their children's behaviours. This lack of focus on fathers is concerning given the consistent evidence of the beneficial effects of engaged fathers for all areas of child development (McWayne et al., 2013; Wilson & Prior, 2011).

The major strength of this study is its large number of parent-child pairs with data on MVPA and dietary intake. We were able to collect self-reported data from mothers, fathers, and children within one family. This data collection has allowed us to quantify the independent contributions of each parent. The present study also has some limitations. First, a questionnaire was used to assess MVPA, which may influence the reliability of the data due to imprecise measurement and possible socially desirable answers. Furthermore, this study identified the DQS by assessing the intake of fruits, vegetables, snacks, and SSBs. Although no validated questionnaire was used, such as the food frequency questionnaire, it is assumed that the applied DQS comprises important components of a person's dietary intake pattern, which may not necessarily be the case It should also be noted that the sample was from a 2015–2016 cohort and may be dated in terms of societal changes in parental roles (e.g., changes in fathers' roles, parents working from home more often). Finally, the non-response analysis in this study showed selection towards a study population of families with high socioeconomic status and children of Dutch origin, compromising the generalisability of this study's results towards more disadvantaged populations.

4.1. Implications

This study highlights the importance of a family-based approach that includes both parents in interventions aimed at stimulating a healthy dietary intake and PA because both parents play an essential role in shaping their children's MVPA and dietary intake in a sex-specific manner. Encouragement of including both parents in interventions may improve the efficacy of lifestyle interventions by paying attention to the fathers' daily child care's positive influence on their children, which is independent of the mothers. Moreover, fathers could play an active role in their sons' healthy diet. Improving the efficacy of lifestyle interventions is important because PA and dietary intake considerably benefit their children's future health and well-being.

5. Conclusion

This study shows a positive association between parent-child MVPA and dietary intake. Both parents' MVPA and dietary intake contribute to children's MVPA and dietary intake scores independently of each other. However, the association between father-child MVPA was only present for fathers with high levels of involvement. This indicates that fathers also have a profound role in their child's PA and dietary intake, complementary to mothers and vice versa, in a sex-specific manner.

Ethics approval and consent to participate

Approval for the ABCD-study was obtained from the Central Committee on Research involving Human Subjects in the Netherlands, the Medical Ethical Committees of the participating hospitals, and from the Registration Committee of the Municipality of Amsterdam. Written informed consent was obtained from all participants.

The Ethics approval numbers for the different parts of the ABCD-study are:

- Pregnancy questionnaire: METC AMC 02/039#02.17.392
- Questionnaires and health check at age 11–12: METC AMC 2015_154#B2015655a.

CRediT authorship contribution statement

SK, HL and TV contributed to the design of the study. SK and TV performed the data analyses. SK, HL and TV wrote the first draft of the manuscript. All authors (SK, HL, RH, CR and TV) reviewed and edited the manuscript. All authors have read and agreed to the final version of the manuscript.

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Consent for publication

Not applicable.

Declaration of competing interest

None of the authors have any declaration of interest to declare.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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