In dental literature the number of longitudinal studies, focussing on dental caries and its determinants in preschool children is limited, in comparison to older age-groups. Longitudinal studies performed are mostly restricted to bacteriological variables. As a part of a caries risk study in preschool children, caries prevalence and several determinants of dental caries have been longitudinally recorded in 2-to-5.5-year-old children. This paper describes on a group level caries prevalence and various determinants of dental caries, during the three-year observation period.

Materials and methods

Between October 1985 and June 1987 parents of all new patients, younger than three years of age, and visiting the child dental health center in Nymegen, The Netherlands, were asked for permission to enroll their children in the study (n = 291). Two hundred and fifty-two children, with an average age of 2.3 years (range 1.9 to 2.8 years), participated (49 percent boys and 51 percent girls). At the age of five years, 193 children were still in the study (Table 1). During the study, dental treatment was provided according to the standard protocols of the clinic: at every check-up, information about diet, use of fluoride at home, and oral hygiene procedures were given to children and parents. If clinical signs of initial caries lesions were present, a fluoride varnish was applied topically (49.2 percent of the children received the varnish). In the three-year observation period, the children were examined at six-month intervals until the age of five years. Final examinations took place between 1988 and 1990.

Data were collected by interviewing the accompanying adult and by performing intraoral examinations of the child and the parent. At the final examinations, bite-wing radiographs were taken.

Social background of the child was based primarily on the level of education of the mother. Only when the father of the child was the primary caretaker, was the level of education of the father used. The level of education was divided into three categories (low level: primary school or elementary vocational training; middle level: secondary or high school education; high level: university training).

At six-month intervals, the dietary habits of the child were recorded, based on a twenty-four-hour recall methodology, while a seven-day diet diary was kept at base-
Table 1 □ The various age-groups and number of children belonging to each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age range</th>
<th>Average age in years</th>
<th>Number of children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>1.00-1.49</td>
<td>1.2</td>
<td>182</td>
</tr>
<tr>
<td>Group 2</td>
<td>1.50-2.00</td>
<td>1.7</td>
<td>183</td>
</tr>
<tr>
<td>Group 3</td>
<td>3.00-3.49</td>
<td>3.2</td>
<td>197</td>
</tr>
<tr>
<td>Group 4</td>
<td>3.50-3.99</td>
<td>3.8</td>
<td>195</td>
</tr>
<tr>
<td>Group 5</td>
<td>4.00-4.49</td>
<td>4.3</td>
<td>197</td>
</tr>
<tr>
<td>Group 6</td>
<td>4.50-4.99</td>
<td>4.7</td>
<td>195</td>
</tr>
<tr>
<td>Group 7</td>
<td>5.00-5.50</td>
<td>5.3</td>
<td>193</td>
</tr>
</tbody>
</table>

line. The daily number of times food was ingested were counted, and special note was made of those (including beverages) containing fermentable carbohydrates. When the interval between food ingestions was less than twenty minutes, they were scored as one.

The use of fluoride at home (in tablets or toothpaste, based on information received from the parents) was recorded at each examination. Although all parents were given the same instructions, personal interpretations of those instructions were expected to vary. Type and amount of toothpaste used per brushing was recorded (no toothpaste at all, toothpaste without fluoride, toothpaste with a low concentration (0.025 percent) of fluoride, toothpaste with fluoride (0.1-0.15 percent) but only a small amount (< 1 gr), and toothpaste with fluoride (0.1-0.15 percent) equal to or more than 1 gr). Additionally the number of brushings per day as well as the total daily ingestion of fluoride tablets was recorded. Assuming that about a third of the toothpaste will be ingested, the total daily intake of fluoride was calculated by multiplying the intake from toothpaste with the brushing frequency and adding the daily fluoride ingestion from the tablets.

Caries was assessed by visual examination, using a mirror and probe. After drying the teeth with an air-stream, each tooth surface was assessed and the observations recorded, according to the following criteria: no signs of caries, white spot with intact enamel, dark (yellow/brown) discoloration of intact enamel, discoloration accompanied by loss of surface continuity of enamel, cavity in the dentin without visible loss of enamel, cavity progressing into dentin, restoration, tooth not yet erupted, or missing due to extraction. White discolorations in the enamel, developmental in origin, were frequently present in the study population and hampered the diagnosis of white spot lesions. The white spot lesions were separately recorded in order to prevent an overestimation of caries activity. Bitewing radiographs were taken under standardized conditions at the age of five years (final examination). Caries on the bitewing radiographs was independently diagnosed by two experienced dentists and scored according to criteria recorded by Marthaler. In case of a difference in diagnosis, consensus was obtained by re-examining the bitewing radiographs. In this paper, the diagnosis "caries lesion" is presented separately for three evidential categories:

- **dₙ** = Dark discoloration, loss of enamel surface continuity or lesions into the dentin.
- **dₙ** = Loss of enamel surface continuity or dentinal lesions.
- **dₙ** = Lesions into the dentin.

On the basis of these observations dₙₚₙₙ, dₙₙₙₙ and dₙₙₙₙ scores were calculated.

The oral cavity of the parent who was most involved with the education of the child (usually the mother) was visually inspected and the DMFT status recorded according to the WHO criteria.

Presence of plaque and gingivitis were scored in a simplified modification of the Suomi-Barbano-index and the plaque-index by Silness and Löe. Four sites in the mouth were examined: in the maxillary arch, the buccal surfaces and in the mandibular arch, the lingual surfaces of the most distal molars, respectively.

The plaque scores were defined as: 0 = no plaque present, 1 = a thin layer of plaque adhering to the marginal gingiva and the joining tooth surface (plaque becomes only visible when using a probe), 2 = soft debris visible on the gingiva and tooth surface. Gingivitis was scored as: 0 = no signs of inflammation, 1 = mild discoloration but no bleeding after probing, 2 = discoloration accompanied by bleeding, spontaneous or after a gentle contact with a periodontal probe. The average scores for the four sites were calculated.

The data regarding the 198 children were re-grouped. Each group represented a half-year age-interval. From the children entering the study (n = 252) 182 were present in group 1 (range 1.9 to 2.5 years) and 70 started the study in age-group 2 (range 2.5 to 3.0 years).

Analysis of the data was accomplished with the Spearman rank correlation.

RESULTS

The average numbers of food and sugar ingestions per day (according to the twenty-four-hour recall results) for various age-groups are presented in Figure 1. No significant age effect on the dietary habits was found. The total daily number of food ingestions (including meals, drinks and snacks) showed a range of four to fourteen, while the number of sugar-containing food ingestions...
ranged from one to ten. In every age-interval, statistically significant \( (p < 0.01) \) correlations between the daily number of food ingestions and the number of sugar-containing food ingestions were found (range .45 to .55). At baseline the dietary information obtained with the twenty-four-hour recall method was compared to the information obtained from the seven-day diet diary. The twenty-four-hour recall method showed an average number of daily food ingestions of 7.0 \((SD = 1.6, \text{range } 4 \text{ to } 13)\) and an average number of daily sugar ingestions of 4.6 \((SD = 1.7, \text{range } 1 \text{ to } 10)\). Similar results were obtained with help of the seven-day diet diary: all food ingestions on average 6.9 \((SD = 1.5, \text{range } 4 \text{ to } 12)\), sugar ingestions on average 4.5 \((SD = 1.5, \text{range } 1 \text{ to } 9)\). The correlation between the information collected with the diet diary and that collected with the twenty-four-hour recall method was low \((r = .43 \text{ for the food ingestions}; r = .52 \text{ for the sugar intakes})\), but statistically significant \((p < 0.05)\).

Use of fluoride, administered in tablets or toothpaste, is presented in Figures 2 and 3. The percentages of children using no fluoride tablets were low, but remained fairly constant (10-20 percent). The percentages of children using no toothpaste gradually decreased with increasing age. Fewer than 40 percent of the children used “toddler” toothpastes with a low fluoride content. The frequency of brushing increased slightly with increasing age; a small percentage of the children had their teeth brushed three times daily (Figure 4). As a result of the increase in the daily number of fluoride tablets and in the brushing frequency, using fluoride-containing toothpastes, the total fluoride ingestion with increasing age from 0.4 to 0.75 mg fluoride daily.

The average dmfs-scores (visual examination only) for the different age-groups are shown in Table 2. The percentages of caries-free children in the various age-groups are shown in Table 3. Combining the results of clinical and radiographical examination, the average \(d_{mfs} \) score and \(d_{mfs} \) score became 2.1 and 1.8, respectively. Only 51 percent of the children were free from \(d_{mfs} \)-type lesions and restorations; 57 percent of the children had a \(d_{mfs} \) score of zero.

Average plaque- and gingivitis scores, which may vary from 0 to 2, are presented in Figure 5. At every age significant negative correlations were found between the level of education of the mother and the daily number of food ingestions \((r = .19 \text{ to } .24, \ p < 0.05)\) and the number of sugar-containing food ingestions \((r = .20 \text{ to } .33, \ p < 0.01)\) of their child. The low correlations \((r < -.20)\) between the level of education and the oral hygiene variables of the child, expressed by average plaque and gingivitis scores, were only of bor-
derive significance (p < 0.05) at the elder age-intervals. The level of education and the DMFT score of the mother measured at baseline, were correlated with the \(d_{\text{mfs}}\) score of the child and shown in Figure 6. Between the level of education of the mother and the \(d_{\text{mfs}}\) score of the child, a negative correlation was found, which became stronger with increasing age of the child. This effect was not observed for any of the other combined variables.

The correlations between the daily number of food ingestions and sugar-containing-food ingestions and the \(d_{\text{mfs}}\) scores at the various age-intervals never exceeded 0.23 (p < 0.01).
Figure 4. Percentage of children by tooth-brushing frequency at various ages.

Table 2 - The average clinical dmfs-scores and standard deviations at various age-intervals.

<table>
<thead>
<tr>
<th>Age interval (yrs)</th>
<th>( d_{mfs} )</th>
<th>SD</th>
<th>( d_{mfs} )</th>
<th>SD</th>
<th>( d_{mfs} )</th>
<th>SD</th>
</tr>
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<tbody>
<tr>
<td>1.92-2.49</td>
<td>.18</td>
<td>.43</td>
<td>.01</td>
<td>.15</td>
<td>.01</td>
<td>.15</td>
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<tr>
<td>2.50-2.99</td>
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<td>1.70</td>
<td>.14</td>
<td>.72</td>
<td>.03</td>
<td>.31</td>
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<td>2.36</td>
<td>.27</td>
<td>1.67</td>
<td>.11</td>
<td>.51</td>
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<td>1.80</td>
<td>.45</td>
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<td>2.45</td>
<td>.69</td>
<td>1.98</td>
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<td>3.98</td>
<td>1.17</td>
<td>3.02</td>
<td>1.60</td>
<td>2.68</td>
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</table>

Table 3 - Percentage of caries-free children (\( dmfs = 0 \)) upon visual examination according to average ages.

<table>
<thead>
<tr>
<th>Group</th>
<th>( dmfs = 0 )</th>
<th>92.7</th>
<th>99.4</th>
<th>99.4</th>
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<tbody>
<tr>
<td>1.92-2.49</td>
<td>95.4</td>
<td>94.1</td>
<td>97.3</td>
<td></td>
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<tr>
<td>2.50-2.99</td>
<td>70.0</td>
<td>91.3</td>
<td>94.4</td>
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</tr>
<tr>
<td>3.00-3.49</td>
<td>65.7</td>
<td>90.4</td>
<td>92.9</td>
<td></td>
</tr>
<tr>
<td>3.50-3.99</td>
<td>56.3</td>
<td>82.7</td>
<td>86.3</td>
<td></td>
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<tr>
<td>4.00-4.49</td>
<td>50.8</td>
<td>77.7</td>
<td>79.8</td>
<td></td>
</tr>
<tr>
<td>4.50-4.99</td>
<td>47.8</td>
<td>71.9</td>
<td>78.8</td>
<td></td>
</tr>
<tr>
<td>5.00-5.50</td>
<td>47.8</td>
<td>71.9</td>
<td>78.8</td>
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</table>

DISCUSSION

In preschool children, measured at the group level, very few showed other than minimal changes in their diet habits with increasing age. Nevertheless, the composition of the diet may have changed, but this information cannot be accurately determined from the twenty-four-hour recall method, because one has to rely on the memory of the parent, which may lapse because of a distraction or absence from home. This will result in an underestimation rather than an overestimation of the actual food ingested. The underestimation will probably increase when the child gets older, as it will spend more time away from the parent. On a group level, a close agreement between the diet diary and the twenty-four-hour recall findings was found, in contrast to the correlation on an individual level. Low correlations were

No statistically significant correlations were found between the amount of fluoride ingested or the frequency of tooth brushing and the \( d_{mfs} \) score.

Between plaque and gingivitis scores and the \( d_{mfs} \) score, significant (\( p < 0.05 \)) correlations never exceeded 0.21.
found between the diet scores (according to the twenty-four-hour recall method) and the dmfs scores. The importance of the diet is demonstrated, however, in several human studies.\textsuperscript{11-14} There are several explanations for the low correlations between the diet data and the dmfs scores in the present study. The correlations between the diet habits and the caries prevalence will be low, when the caries prevalence is low and the differences in diet habits are small.\textsuperscript{15} The low correlations may also be partially explained by a low validity of the diet data.

It can be estimated that the total daily ingestion of fluoride from toothpaste and fluoride tablets increased with increasing age, and to the age of 3.5 years statistically significant differences (p < 0.01) existed. The number of children who were irregular users or used no fluoride at all remained fairly constant. With increasing age more fluoride tablets per day were used. In the youngest age-group almost 40 percent of the children did not use a fluoridated toothpaste. The consumption of toddler toothpaste (with a low fluoride content) did not increase. To parents who preferred to have one type of toothpaste for all the members of the family, instructions were given to reduce the volume of toothpaste applied to the brush of the young children. We assumed that most of the children received very small doses of fluoride from their toothpaste compared to the amount received from fluoride tablets. The use of fluoride containing toothpastes by 60 percent of the children was low when compared to 88 percent of the five-to-six-year-old children in another study in The Netherlands.\textsuperscript{16} The frequency of tooth brushing was relatively low and only a small number of children brushed three times a day. In case of a low frequency of brushing in combination with a small amount of toothpaste, it is doubtful that the ingestion of fluorides would be optimal without ingestion of fluoride tablets. On a group level, the variable fluoride ingestion demonstrated no statistically significant correlation with the caries score, probably as an effect of the high level of fluoride ingestion in the total study population. The percentage of children using no fluoride at all was low and especially in this group the parents should have been aware of the importance of the diet in the development of dental caries.

Until the age of 3.5 years, the plaque and gingivitis scores increased; but statistically significant differences were found only between the youngest age-group and the other age-groups. Possible explanations may be less control by the parents of the oral hygiene of the children or changes in the number of teeth present in the mouth. After eruption of the second primary molars, their posterior location in the mouth may hamper the effectiveness of tooth brushing. The correlations of the plaque and gingivitis scores with the dmfs score were very low. This was probably the result of the lower caries preva-
The caries experience (dmfs score) was low in comparison to other studies performed in The Netherlands. Truin et al (1991) found about 60 percent of the five-year-old children to be caries free. He found, however, the average dmfs score to be twice as high. In the present study large differences were also found between the percentages of children considered to be "caries free" according to the dmfs score or dmfs score. These results confirm the conclusions of Rimmer and Pitts (1991) that variations in the diagnostic thresholds influence the percentage of subjects who are considered to have sound teeth. In their study, especially the inclusion of initial caries lesions (dark discoloration without detectable loss of substance) resulted in scores that are significantly different from the caries scores excluding this type of defect.

The relation between the socioeconomic status and the caries experience in young children was demonstrated in several studies. A possible explanation for the correlation between the caries experience in the child and the education of the parents could be that more highly educated people demonstrate a more dental minded behavior: they eat less sweets, brush their teeth more often and visit their dentist more regularly. Granath Kinnby et al (1991) found that the level of education of the parents did not influence their knowledge about oral hygiene, diet, and use of fluorides, but did affect their ability to put the knowledge into practice. The level of education was statistically significantly higher among parents of healthy children, therefore, than among those of diseased children. Similar findings were
observed in the present study. At every age-interval, the level of education was negatively correlated with the number of daily food ingestions and sugar-containing food ingestions in particular. Grytten et al (1988) found no relationship between the level of education of the mother and the intake of fluoride tablets by three-year-old children. A low but significant relationship was found, however, between the number of missing teeth of the mother, her dental attendance pattern and her level of education, and the caries experience in her child. In the present study, the level of education of the mothers showed a higher (negative) correlation with the caries experience of the children than the DMFT score of the mothers. With increasing age of the child, the correlation between the level of education of the mother and the caries score of the child gradually increased. This is probably the result of the children being subjected to unfavorable conditions for a longer period of time. The relatively low correlations of most of the variables with dental caries will be partially explained by the cross-sectional analysis and the fact that the determinants of the caries process at present should be searched for in the past. In a cross-sectional study the factor exposure time is not taken into account. At the time that caries is clinically present the mothers showed a higher (negative) correlation with the intake of fluoride tablets by three-year-old children. A low but significant relationship was found, however, between the number of missing teeth of the mother, her dental attendance pattern and her level of education, and the caries experience in her child.

REFERENCES
