Caries Risk Factors and Risk Indicators in Preschool Children

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The more I learn,

the more I realize how little I know

SOCRATES

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ABSTRACT

Background and aim: Caries is one of the most common diseases in preschool children. Pain, infections and sleep disturbances in childhood caries can adversely affect body weight and nutritional ability and may raise the risk of the disease continuing into adulthood. Modern dentistry is able assess caries risk and weight risks and protective factors on an individual basis. The general aim of this thesis was to determine risk factors and risk indicators for caries in preschool children through analyses of oral, environmental, and social factors.

Patients and Methods: Paper I, II and III followed the dental records for children ages 1-6 years. At age 1, data on oral risk factors, environmental factors and presence of mutans streptococci were retrieved; at ages 1 and 3, caries risk assessment were performed and at ages 3 and 6 years, caries status were collected. Factors associated to caries risk were studied. Paper IV, a registry-based study that retrieved data on caries status from 3 to 6 years of age. The data included caries risk assessment and social factors from ages 3 to 5 years. Caries risk assessment models were designed, adding environmental and social factors, to established caries risk assessment.

Results*:* *Presence of mutans streptococci* at age 1 year were associated to caries at 3 and 6 years of age. Environmental factors at age 1 year, *siblings with caries,* and *beverage other than water between meals* were associated to presence of MS (Paper I) and together with *night meals* associated to caries at 3- and 6-years of age (Papers II, III). Social factors, *foreign background*, *low parental education level*, *three or more siblings* and *living in a one-parent family* were associated to caries at 6 years of age. Supplementing a caries risk assessment with environmental and social factors in predictive models improved the ability of the model to predict caries progression, the predictive ability of the assessment improved more at younger ages than at older ages

(Papers II, III, IV), and was higher when intervals between the risk assessment and oral examination were shorter (Papers III and IV).

Conclusion: Risk factors found during an oral examination as well as information about the child's environmental- and social conditions should be included in a caries risk assessment. Environmental and social indicators at one year of age regarding; *siblings with caries, night meals* and *beverage other than water between meals* can replace saliva tests to find the risk factor *mutans streptococci*. Social indicators have a greater impact on younger children's caries risk compared to older children.

Keywords: dental caries susceptibility, oral examination, oral health, dental care for children.

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SAMMANFATTNING PÅ SVENSKA

Bakgrund och syfte: Karies är en av de vanligaste sjukdomarna hos förskolebarn. Karies i barndomen kan orsaka smärta, infektioner och sömnstörningar. Detta kan påverka barnets tillväxt negativt vad gäller kroppsvikt och näringsupptag. Karies i barndomen tenderar att fortsätta in i vuxen ålder. För att undvika att karies utvecklas är kariesriskbedömning, en balans mellan risk- och skyddsfaktorer på individuell grund, en viktig del av modern tandvård. Det övergripande syftet med denna avhandling var att fastställa riskfaktorer och riskindikatorer för karies hos förskolebarn genom att analysera orala-, miljö- och sociala faktorer.

Patienter och metoder: Papper I, II och III följde tandjournalerna för barn i åldrarna 1–6 år. Vid 1 års ålder hämtades data om orala riskfaktorer, miljöfaktorer och förekomst av mutans streptokocker; vid 1 och 3 års ålder utfördes kariesriskbedömning och vid åldrarna 3 och 6 år insamlades kariesstatus. Sambandet mellan olika faktorer och karies analyserades. Paper IV, en registerbaserad studie som hämtade data om kariesstatus från 3 till 6 års ålder. Uppgifterna inkluderade kariesriskbedömning och sociala faktorer från åldrarna 3 till 5 år. Kariesriskbedömning, miljö- och sociala riskfaktorer ingick i designade riskmodeller.

Resultat: Förekomst av mutans streptokocker vid 1 års ålder var associerad med karies vid 3 och 6 års ålder. Miljöfaktorer vid 1 års ålder, syskon med karies och annan dryck än vatten mellan måltiderna var associerade med förekomst av mutans streptokocker (Paper I) och tillsammans med nattmål associerade med karies vid 3- och 6-årsåldern (Papper II, III). Sociala faktorer, utländsk bakgrund, föräldrar med låg utbildningsnivå, tre eller fler syskon och att leva i familj med en förälder var associerade med karies vid 6 års ålder. Att komplettera en kariesriskbedömning med miljö- och sociala faktorer i prediktiva modeller förbättrade modellens förmåga att förutsäga kariesprogression, bedömningens prediktiva förmåga förbättrades mer i yngre åldrar än i äldre åldrar (Papper II, III, IV), och var högre när intervallen mellan riskbedömning och tandundersökning var kortare (Papper III och IV).

Slutsats: Riskfaktorer funna vid tandundersökning samt uppgifter om barnets miljö- och sociala förhållanden bör inkluderas i en kariesriskbedömning. Miljö- och sociala indikatorer vid ett års ålder beträffande; *syskon med karies, nattmål* och *annan dryck än vatten mellan måltider* kan ersätta salivtest för att

hitta riskfaktorn *mutans streptokocker*. Sociala indikatorer har större inverkan på yngre barns kariesrisk jämfört med äldre.

LIST OF PAPERS

This thesis is based on the following papers, referred to in the text by their Roman numerals.

I. Ingemansson-Hultquist A, Lingström P, Bågesund M. Risk factors for early colonization of mutans streptococci – a multiple logistic regression analysis in Swedish 1-year-olds. BMC Oral Health 2014, 14:147. doi: 10.1186/1472-6831-14-147.

II. Hultquist AI, Bågesund M. Dentin caries risk indicators in 1-year-olds. A two-year follow-up study. Acta Odontol Scand. 2016;74(8):613-619. doi: 10.1080/00016357.2016.1227085

III. Hultquist AI, Brudin L, Bågesund M. Early childhood caries risk assessment in 1-year-olds evaluated at 6-years of age. Acta Odontol Scand. 2021;79:103-111. doi: 10.1080/00016357.2020.1795247.

IV. Hultquist AI, Levinsson A, Robertson A, Sabel N. Integrating Oral and Social Factors in Individual Caries Risk Assessments in Preschool Children - a Registry-Based Study. Eur Arch Paediatr Dent. 2024 Aug 5. doi: 10.1007/s40368-024-00928-0.

CONTENTS

ABBREVIATIONS

AAPD	American Academy of Pediatric Dentistry
AI	Artificial Intelligence
AUC	Area under the ROC curve
CAMBRA	Caries management by risk assessment
CAT	Caries risk assessment tool
CFU	Colony forming units
CI	Confidence interval
deft	Decayed, extracted, filled teeth (primary teeth)
dmft	Decayed, missing, filled teeth (primary teeth)
dt	Decayed teeth (primary teeth)
DT	Decayed teeth (permanent teeth)
ECC	Early childhood caries
et al.	et alium
FP	False positive
FN	False negative
IAPD	International Academy of Pediatric Dentistry
MS	mutans streptococci
NPV	Negative predictive value
OR	Odds ratio
PDS	Public Dental Service
PPV	Positive predictive value
ROC	Receiver operating characteristic

SCB	Statistiska centralbyrån (Statistics Sweden)
SD	Standard deviation
SES	Socioeconomic status
SKaPa	Swedish Quality Registry for Caries and Periodontal Disease
TN	True negative
TP	True positive
UNCRC	United Nations Convention on the Rights of the Child
WHO	World Health Organization
4–5	Ages 4 and 5 years

DEFINITIONS IN SHORT

Caries experience	Manifest, missing/extracted due to caries, and filled teeth, deft (1, 2)
Caries risk	The probability that caries lesions will appear or progress if conditions remain the same within a stated period (2, 3)
Early Childhood Caries	One or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled surfaces in any primary tooth of a child under 6 years age (4)
Incidence	The proportion of new cases of disease during a pre-defined time period (2)
Initial caries	Enamel caries (a non-cavitated caries lesion), also known as a white spot lesion
Manifest caries	Dentin caries (a cavitated caries lesion)
Negative predictive value	The ratio of patients diagnosed with no disease to those with negative test results
Positive predictive value	The ratio of patients diagnosed with disease to those with positive test results
Prevalence	The proportion of disease in a population at a specific time (2)
Primary prevention of ECC	Upstream intervention on the community level and prevention of disease at the individual level (5)
Secondary prevention of ECC	Prevention of progression, or stimulation of caries regression (5)

Sensitivity	The test's ability to find the proportion who have disease
Specificity	The test's ability to find the proportion who do not have disease
Tertiary prevention of ECC	Involves both non-invasive and invasive preventive management (5)

1 INTRODUCTION

We know that caries has existed for millennia through documentation of the remains of deceased people. In modern times, the etiology of caries has been discussed and investigated. One break through was the Vipeholm investigation in the 1950s, which found caries to be associated with sugar and intake frequency (6).

The etiology of caries is now well known, as are the prophylactic actions that, at individual, professional, and community levels combined, will prevent caries (4, 7, 8). Despite current knowledge, caries remains a major health problem in all economies, whether advanced or emerging and developing (9-13). Globally, caries is one of the most common diseases in preschool children, causing pain and infection (14-16). Poor oral health affects more than general health and quality of life; the consequences of childhood caries also include physical growth (13, 15-20). One systematic review found caries experience in the primary dentition to be 46% globally; however, regional differences were large (11).

1.1 CARIES INDEX

Caries prevalence is defined as the proportion of individuals in a population with caries at a specific time (2). Another term, caries experience, is the proportion of individuals in a population with caries lesions or untreated caries, restorations, and/or missing teeth due to caries, at a specific time (2). Caries experience is measured by the number of decayed, missing due to caries, and filled primary teeth (dmft) or the number of decayed, extracted due to caries, and filled primary teeth (2). In 1938, Klein stated that untreated caries is only part of the total caries experience (1). Teeth that are missing due to caries and filled teeth, which are previously decayed teeth that have received restorative treatment, should be included in prevalence rates (1). Klein introduced the DMFT index in 1938 for assessing caries prevalence in the permanent dentition; since then, perception has changed: caries prevalence includes the proportion of individuals with active caries (DT) (1, 2). The World Health Organization (WHO) has described these terms of the standard epidemiological indicator for the primary and permanent dentitions (21).

1.2 EPIDEMIOLOGY IN PRESCHOOLERS

Early childhood caries (ECC) is defined as caries in children ages 6 years and younger (4, 22).

In recent decades, many regions in the world have experienced a decrease in the prevalence of dental caries, but for those affected, it is a problem that reduces patient quality of life and is costly for society (5, 10, 23, 24).

The dental health of Swedish children is generally considered good. In the last 15 years, about 5% of 3-year-old Swedish children and 25% of 6-year-old children have caries experience (25). Still, Sweden did not achieve the 2016 WHO goal having 80% or more of all 6-year-old children should be caries free (26). In 2022, caries experience of 6-year-old Swedish children varied between 12% and 26%, depending on region (27).

Table 1. Variation in caries experience nationally (in Sweden) and in Östergötland[a] and Kalmar[b] Counties.

Year	Caries experience (%)	
	Sweden [28-30]	Counties[c] [31]
3-year-olds		
2004	5	7[a]
2012	4	6[a]
2015	5	5[b]
6-year-olds		
2007	26	31[a]
2015	25	25[a]
2018	24	26[b]

[c]Personal communication from Region of Kalmar

1.3 PATHOGENESIS

The caries process is complex, consisting of an active breakdown process of tooth substance. The breakdown is caused by acid-producing bacteria, mainly mutans streptococci. The biofilm that is found on all tooth surfaces contains bacteria that form dental plaque. The bacteria in the biofilm mainly feed on substances in the saliva, but many of them can use the sugar in our diet and produce acid, mainly lactic acid. This causes the pH to drop and allows protons and hydrogen ions to migrate between the calcium phosphate crystals that compose the tooth surface. Eventually, these crystals begin to dissolve, and the released calcium and phosphate ions migrate out of the tooth in a demineralization process (32).

Three modern hypotheses model the interaction of bacteria on caries: The *specific plaque hypothesis*, in which only a few species are actively involved

in caries disease (33); the *nonspecific plaque hypothesis*, in which caries depends on the overall activity of the total plaque microflora (34); and the *ecological plaque hypothesis*, in which caries is a result of a shift in the balance of the microflora caused by changes in local environmental conditions (35).

1.4 CARIES RISK FACTORS AND RISK INDICATORS IN PRESCHOOL CHILDREN

Caries is a multifactorial disease. It is caused by numerous species of bacteria, depends on dietary habits, is affected by salivary dysfunction, and is influenced by the social determinants of health (36). Risk factors and risk indicators, concepts that are often confused, affect caries development in preschool children (2, 37).

Risk factors are directly involved in the caries process itself. If a caries risk factor decreases or ceases to exist, caries development will also decrease. Risk indicators are not involved with the oral caries process but are surrounding, coexisting factors, for example, social factors (37, 38). Risk indicators exist outside of the individual and are controlled by the social determinants of health (39).

1.5 ETIOLOGY

1.5.1 ORAL RISK FACTORS

Risk factors in the oral environment are the factors that breakdown of the tooth, demineralization. Oral risk factors are dietary habits, both content and frequency of intake; oral hygiene, such as plaque on the teeth; and biological factors, such as cariogenic bacteria and amount of bacteria (5, 15, 40, 41). Factors during the child's first year of life affect the development of ECC, and this includes acquisition of cariogenic bacteria and behavioral risk factors acquired in the environment in which the child grows up (42). Selwitz et al. found that poor oral hygiene with bacterial accumulation (plaque) are favorable factors for caries development (43). Grindefjord et al. found an association of consumption of sugar-containing beverages with candy at 1 year of age and dental caries at 3.5 years age (44). Bankel found that frequent intake of sweetened products increases the risk of caries development in preschool children (45). Night meals after the first year of life and sweet drinks between meals are strong risk factors for caries (5, 15, 46, 47)

The microbiota in the oral cavity of a new-born child is sterile (48). The erupted tooth presents an opportunity for mutans streptococci to colonize; mutans streptococci bacteria need a tooth surface that they can adhere to, although studies have shown that pre-dentated children can also have mutans streptococci colonization (42, 49). Mutans streptococci colonize after transmission from parents or siblings via saliva (42, 49). Leong et al. reported that maternal factors influence bacterial acquisition, while bacterial growth was mediated by oral health behaviors and dietary habits (42). The Grindefjord et al. study found an association of mutans streptococci at age 1 year with dental caries at age 3.5 years (50). In younger children, presence of mutans streptococci is considered a caries risk factor (41, 45, 51, 52). A recently erupted tooth is naturally more sensitive to acid than a tooth that has been erupted for a longer period of time, because the tooth surface is not hardened by fluoride (53, 54). Laitala says that avoiding an early colonization of mutans streptococci can lead to future positive effects on caries development (55).

1.5.2 SOCIAL AND ENVIRONMENTAL RISK INDICATORS

Individual lifestyle and behavior are influenced by the social environment of the individual. Socioeconomic factors, which include educational level, disposable income, and economic conditions, govern the social factors affecting the individual (38, 39, 56). In 1991, Whitehead and Dahlgren described the multifactorial nature of health, an interaction between individual, family, and community levels affecting health, in a model known as the Policy Rainbow (Figure 1) (39). Overall health, and oral health in particular, is influenced by behaviors that are a consequence of the environment in which people are born, grow up, and live (15, 38, 57).

A child's environment affects their oral health; as parents provide the primary social role for the child, the socioeconomic status of the parents is highly influential (58). Environmental risk factors associated with the development of caries include eating habits, food and beverage content, consumption frequency, and oral hygiene habits (42). Social risk indicators that influence environment and behavior include country of birth, education, and income, which have a clear connection with the risk of having developed caries at the age of 6 (59).

Studies conducted in Sweden have found that maternal level of education, view of dental health, and own health have a large influence on the risk of tooth

decay in young children (59, 60). In the Andre-Kramer et al. study, parental foreign background, level of education, and income were connected with the risk of primary dentition caries in their children (61). The study agrees with Anderson et.al., who found that predictors at age 1 year for developing dental caries in later preschool years were immigrant background and low family income (62). Anil found that low familial socioeconomic status and low parental education are factors to consider when a child should be risk-assessed for future caries (15). Grindefjord found in a study of 1-year-olds that immigrant background and maternal education was associated with dental caries at 3.5 years of age (44).

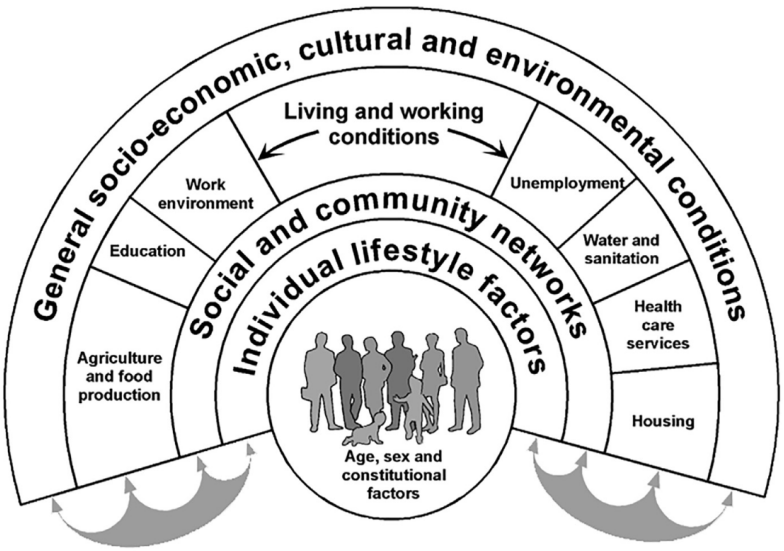


Figure 1. Determinants of health (Dahlgren and Whitehead, 1991 (39).

1.6 PROTECTIVE FACTORS FOR YOUNGER PRESCHOOL CHILDREN

Protective factors, factors that can lower the risk of developing caries disease, can be classified as biological or environmental factors. Biological protective factors include fluoride use (toothpaste) and living in a region with naturally or artificially fluoridated drinking water. Fluoride acts on the tooth surface, directly affecting the mineral layer in the enamel and increasing its resistance

to acidic action (63-65). Tooth brushing twice a day with a fluoride toothpaste, under adult supervision or with their help, decreases bacterial counts and adds to the amount of available fluoride (4, 13, 66, 67). Protective dietary habits include eating regularly, restricting in-between meals, drinking water when thirsty, limiting added sugar, and reducing night meals. These are considered biological and environmental protective factors, reducing fermentable carbohydrates (68-70). Repeated recommendations on sugar use state that children under the age of 2 should consume no added sugar; thereafter, they should have only limited access to sugar (4, 20, 71). Good salivary function, as in normal salivary flow and saliva constitution, are biologically protective factors (72). Environmental factors that are socially protective include a nuclear family, a stable family economy, and higher parental education (57, 68, 71).

1.6.1 BREASTFEEDING

Breastfeeding is often discussed from a caries aspect. Opinion is divided on whether breastfeeding is a risk or a protective factor. The updated recommendation from WHO is breastfeeding child after birth and up to 6 month of age- with no other food or beverage provided and thereafter breastfeeding up to 2 years of age (73). Feldens considers that children who are breastfed have a later sugar debut, which supports breastfeeding as a protective factor (20, 71). A Norwegian study found that breastfeeding up to 18 months was not associated with caries in preschool children (74). In contrast, an umbrella review by Panachanadir declared that prolonged breastfeeding (> 12 months), including nocturnal feeding, should be considered a risk factor for ECC (75). Tham concluded that breastfeeding up to 12 months was not associated with an increased risk of caries and could even have protective effects; however, breastfeeding after 12 months had an increased risk of caries (76). Breastfed daily and at night at ages 1–2 years was associated with caries in the Johansson et al. study (47). The teeth of breastfed children are more often colonized by lactobacilli compared to formula-fed children, and lactobacilli inhibit the growth of some streptococci (48, 77). A review study by Shrestha et al. could show no difference in risk of ECC- caries before 6 years of age - between children who were breastfed for less than 24 months and children who were not breastfed (78). Nevertheless, nighttime breastfeeding increased the risk of ECC in preschool children (78). The authors concluded that the included studies had high heterogeneity in this review, so the results should be cautious (78).

1.7 How caries affects the individual

Caries affects the child's quality of life in both the short and long term. In the short perspective, caries causes pain and infection, which can affect eating and sleeping. Growth and nutritional disorders may also result (14-16, 79, 80). Besides guilt and worry, parental quality of life is also affected when their child suffers from the pain of carious teeth (5, 16, 17, 19, 80, 81).

We already know that the presence of caries in the primary dentition is a predictor of caries in the permanent dentition (18, 82-84). Unpleasant dental treatment of caries in young children can also cause future problems and, later, lower quality of life (85-87).

When dental phobia becomes established in childhood, avoidance behavior in adulthood may occur, despite dental treatment needs. This can lead to a need of extensive treatment later in life and high costs to society (10, 87, 88). The Kastenbom et al. study found that dental treatment costs in young, caries-active adults were twice as high, and anxiety and depression more common compared to caries-inactive individuals (87). The Nordrehaug & Åström study in Norway reported that young adults who had had unpleasant dental experiences when they were younger would cancel and avoid dental visits due to fear more often than their peers who had had better dental experiences (89). This is an important argument for prevention of caries at early ages.

1.8 CARIES RISK ASSESSMENT

A caries risk assessment evaluates the risk of caries development in the near future and is a tool for planning treatment and follow-ups (90). Because caries is a multifactorial disease, a caries risk assessment should include all known caries risk and protective factors, and query general health factors (diseases and medications), presence of caries, and social factors, based on an individual level (57, 91). In 2022, the Swedish National Board of Health and Welfare concluded that caries risk assessment in preschool children is commonly based on oral risk factors alone (59). Practices of clinicians vary regarding which risk factors to use, how they should weigh them, and how to identify high risk or low risk individuals (92). Caries risk assessment also has great potential for improving patient knowledge of the reasons for their caries activity and tailoring their care plans and recall intervals (93).

Previous studies have recommended an assessment of caries risk in the child's first year of life, with routine future re-assessments (5, 94). Following the assessment, it is possible to tailor recommendations for the assessed caries risk and caries risk factors. Preventive care is planned for children assessed as having a measurable risk of developing caries. On return visits, caries and caries progression are followed up. Recall intervals are more individualized these days; thus, caries risk assessment must be done accurately as recall length depends on the results of the assessment (95).

Heterogeneous groups are influenced by the caries prevalence in their area, and caries risk assessment is sensitive for different age groups and geographic areas. It is therefore important to calibrate the caries risk method for the population where it will be used (96-98). In this thesis, caries risk assessment in preschool children is discussed, not to be confounded with the overall oral risk assessment.

1.8.1 CARIES RISK ASSESSMENT PROGRAMS

Various methods and programs have been devised for assessing caries risk. No program, however, has yet been shown to be superior to others in predicting caries (94, 97, 99). A caries risk assessment program should be to conserve time at the clinic, since clinic time is limited, and accurate, to support treatment decisions and determination of recall intervals (5, 90, 99).

Known methods for assessing caries risk include the programs Cariogram and Caries Management by Risk Assessment (CAMBRA) and guidelines of the American Dental Association (ADA) and the American Academy of Pediatric Dentistry (AAPD). Clinicians in the Swedish Public Dental Service (PDS) commonly use R2, a computerized risk assessment tool.

1.8.1.1 CARIOGRAM

Cariogram, an algorithm-driven caries risk program, has been used as decision support in recent decades (96, 100-103). To conduct a caries risk assessment with the Cariogram data on biological caries related factors are needed. Data are collected from patient interviews, or the guardians of a child, and from the clinical examination. Caries experience, information on medical history and medications, diet (contents and frequency), presence of plaque, presence of mutans streptococci, fluoride exposure, saliva secretion, and saliva buffer capacity are included in the Cariogram algorithm program (Table 2).

Cariogram includes no environmental or social risk indicators since they are expected to leave an impression on the biological findings.

Cariogram, a computer program, presents its results in five colored sectors: (1) diet; both content and frequency, (2) bacteria; plaque amount and mutans streptococci, (3) susceptibility; fluoride program and saliva factors (4) circumstances; caries experience and related disease (5) "Chance of avoiding caries" (Table 2; Figure 2). When the chance of avoiding caries is high, caries risk is considered small. Five risk categories are used: very low risk, low risk, medium risk, high risk, and very high risk. In the very high risk category, the chance of avoiding caries is 0–20% (Figure 2). The clinician has the opportunity to add notes on personal knowledge of the patient before making the final risk determination. Cariogram also identifies risk factors on an individual level and suggests preventive and treatment measures. The program has been evaluated for use in both children and elderly persons. It was first developed for educational purposes in the dental profession and, later, for informing and discussing with patients (101).

The validity of Cariogram shows good accuracy in school-aged children, adults, and the elderly (100, 104, 105). A prospective study of 10–11-year-old schoolchildren reported an odds ratio (OR) of 53 for the caries increment, that is, in the very high risk group in Cariogram (100). In a population of preschool children with low caries prevalence, the Cariogram showed not to be useful for detecting children at high caries risk, as 50% of the 2-year-old children were assessed in the high caries risk group and 50% of the children had changed risk group at follow-up at age 7 years, and 63% of children were correctly classified (102). In a region with high caries prevalence, Birpou found that the ability of Cariogram to predict caries in preschool children was inadequate (Table 3) (103). Hänsel Peterson concluded that excluding saliva tests in Cariogram reduces the accuracy of caries prediction in school children (106). In another study by Gao, excluding saliva test in preschool children did not improve the sensitivity and the predictive ability in Cariogram (107).

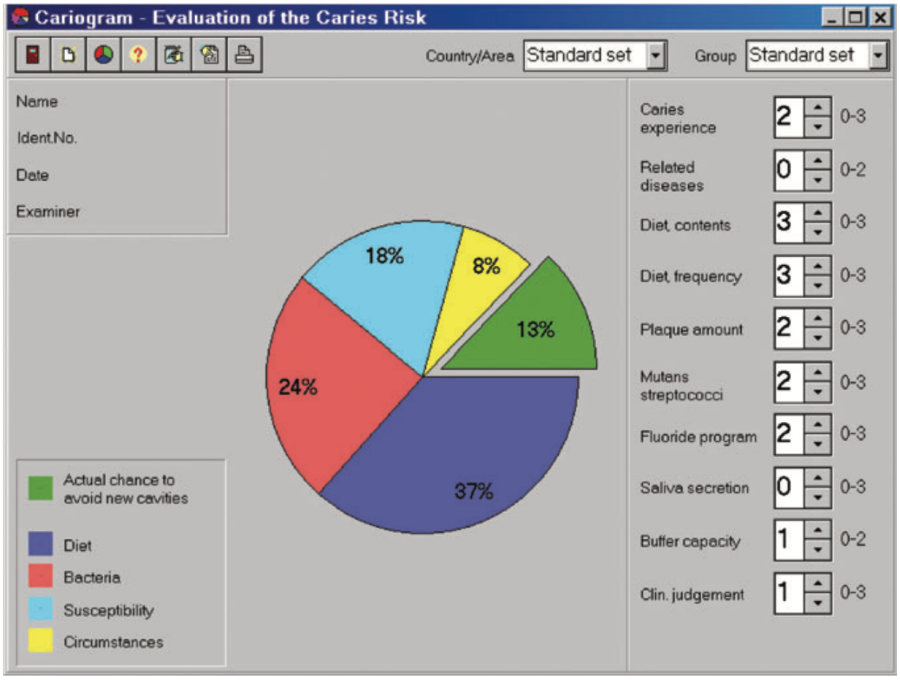


Figure 2. Caries risk and causal factors in Cariogram. In this case, caries risk is high: "Chance of avoiding caries is 13%" (Bratthall 2005).

1.8.1.2 R2

R2 is a risk-assessment algorithm software developed in Sweden in 2008. The PDS in Jönköping and Västra Götaland Counties collaborated with the Department of Dentistry in Jönköping to develop R2. The program is based on dental status variables and modifying factors. R2 includes caries-, periodontitis- and technical risk. In the thesis going forward, only the cariological aspect in R2 is discussed. The clinician interviews the patient or guardians and enters information on modifying factors, such as diet and oral hygiene habits, medical status, use of fluorides, and saliva flow, in R2 (Table 2). The clinician then retrieves caries status, excepting for manifest caries on the occlusal surface, from patient records. R2 compiles an oral health profile based on the modifying factors and data on caries status and presents risk in three levels: low, moderate, or high (Figure 3). The oral health profile can be adjusted manually. In Sweden, R2 is used as a risk assessment tool for both younger and older patients (108). To our knowledge, it has not been validated.

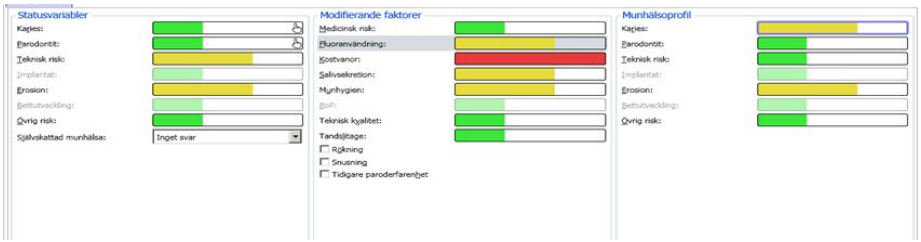


Figure 3. R2 risk-assessment output for Kalmar County. Status variables are presented on the left, modifying factors, in the middle, and the oral health profile on the right (R2 instruction manual).

1.8.1.3 CARIES MANAGEMENT BY RISK ASSESSMENT

Over 20 years ago, the University of California collaborated with the California Dental Association to develop the CAMBRA risk assessment tool (109). It is a reasoning-based program geared for two age ranges: 0–6 years and 6 years through adult. Clinical observations, biological and environmental risk factors, protective factors, and the clinical judgement of the clinician determine the final risk assessment. The version for ages 0–6 years includes questions on frequency of snacking, drinking beverages other than water between meals, parent and sibling history of decay, familial socioeconomic status or health literacy status, and medications that include hyposalivation (Table 2 and Figure 4). CAMBRA queries data on biological and environmental risk factors; environmental risk factors include social risk indicators. Caries risk level is classified in four groups: low, moderate, high, or very high/extreme (57, 110, 111). Several studies have tested the validity of CAMBRA (107, 112). In individuals older than 6 years, validity is good, although 70–88% of high and extremely high caries risk individuals developed new caries at follow-up after 6 years (112). Sensitivity in preschool children was 84% and specificity, 63% (107).

TABLE 2 (Part 1) | Updated CAMBRA caries risk assessment form[#] for ages 0–6 years (January 2021)[##].

Patient Name:	**Reference Number:**		
Provider Name:	**Date:**		
Caries risk assessment component* **(Check yes only in appropriate shaded column)**	**Column 1 Score:–1**	**Column 2 Score: +2**	**Column 3 Score: +3**
Biological or environmental risk factors Question items**		**Check if Yes***	
1. Frequent snacking (more than 3 times daily)			
2. Uses bottle/non-spill cup containing other than water			
3. Parent/primary caregiver or sibling has current decay or a recent history of decay (see high risk description below)			
4. Family has low socioeconomic &/or low health literacy status			
5. Medications that induce hyposalivation			
Protective factors - Question items	**Check if Yes***		
1. Lives in a fluoridated drinking water area			
2. Drinks fluoridated water			
3. Uses fluoride (F)-containing toothpaste at least two times daily-a smear for ages 0–2 years and pea size for ages 3–6 years of 1,000 ppm F.			
4. Has had fluoride varnish applied in the last 6 months			
Biological risk factors - Clinical exam**		**Check if Yes***	
1. Heavy plaque on the teeth			
Disease indicators – Clinical exam			**Check if Yes***
1. Evident tooth decay or white spots			
2. Recent restorations in last 2 years (new patient) or the last year (patient of record)			
Column total score (Columns 2 + 3 –1):	**Column 1 Total:**	**Column 2 Total:**	**Column 3 Total:**
Yes's in columns 1 and 2 only: use the caries balance-below Yes or yes's in column 3 likely indicates high or very high risk			
Final Overall Caries Risk Assessment Category (check) determined as per guidelines below			
LOW ☐ **MODERATE** ☐ **HIGH** ☐ **VERY HIGH** ☐			

Figure 4. The CAMBRA (Caries management by risk assessment) caries risk assessment form for ages 0–6 years (57).

1.8.1.4 AMERICAN ACADEMY OF PEDIATRIC DENTISTRY

The AAPD developed an updated caries risk assessment guidelines in 2006 from the original guideline from 2002 (113). The processes included evaluation by an expert panel. Caries Risk Assessment Tool (CAT) of the AAPD is a reasoning-based tool. CAT forms were designed for infants (age 0–3 years, for use by physicians and other non-dental healthcare providers), and children (0–5 years), and adolescents. The forms for children and adolescents were designed for dental providers.

All forms include data on biological factors, protective factors, and clinical findings. The form for children aged 0–5 years includes 14 items, and the assertions are answered with yes or no (Figure 5). Overall caries risk is divided into three categories: low, moderate, and high risk (Figure 5). The clinician has the opportunity to adjust the result according to clinical findings and personal knowledge of the family before determining the final risk.

Excluding socioeconomic factors, sensitivity was 86% and specificity, 69% (114). In contrast, Gao found a lower decrease in sensitivity and specificity when socioeconomic factors were excluded: 99% and 4%, respectively, in 3-year-old children (Table 3) (107). The researchers did not consider the CAT was useful in low socioeconomic areas though all children automatically were categorized in high risk level, since certain individual factors or indicators are sufficient to justify a "high risk" diagnosis (107).

Factors	High Risk	Moderate Risk	Low Risk
Biological			
Mother/primary caregiver has active caries	Yes		
Parent/caregiver has low socioeconomic status	Yes		
Child has >3 between meal sugar-containing snacks or beverages per day	Yes		
Child is put to bed with a bottle containing natural or added sugar	Yes		
Child has special health care needs		Yes	
Child is a recent immigrant		Yes	
Protective			
Child receives optimally-fluoridated drinking water or fluoride supplements			Yes
Child has teeth brushed daily with fluoridated toothpaste			Yes
Child receives topical fluoride from health professional			Yes
Child has dental home/regular dental care			Yes
Clinical Findings			
Child has >1 decayed/missing/filled surfaces	Yes		
Child has active white spot lesions or enamel defects	Yes		
Child has elevated mutans streptococci levels	Yes		
Child has plaque on teeth		Yes	

Circling those conditions that apply to a specific patient helps the practitioner and parent understand the factors that contribute to or protect from caries. Risk assessment categorization of low, moderate, or high is based on preponderance of factors for the individual. However, clinical judgment may justify the use of one factor (e.g., frequent exposure to sugar-containing snacks or beverages, more than one dmfs) in determining overall risk.

Overall assessment of the child's dental caries risk: High ❒ Moderate ❒ Low ❒

Figure 5. Caries risk-assessment form for children aged 0–5 years, for use by dental professionals AAPD-CAT (American Academy of Pediatric Dentistry Caries Risk Assessment Tool) (113).

1.8.1.5 ASPECTS OF CARIES RISK ASSESSMENT TOOLS

Tables 2 and 3 present differences and similarities between Cariogram, R2, CAMBRA, and the AAPD-CAT.

Table 2. Comparison of four caries risk assessment programs.

Factors and subfactors		Caries risk assessment program			
		AAPD CAT[a]	**CAMBRA[b]**	**Cariogram**	**R2**
Form designed for age (years)		0–5	0–6	0–100	0–100
Clinical Status	• Caries experience	✓	✓	✓	✓
	• White spot lesion	✓	✓		✓
	• Oral hygiene	✓	✓	✓	✓
Microbiological	mutans streptococci	✓		✓	
Saliva	• Flow		✓	✓	✓
	• Buffering capacity			✓	
Dietary habits	Content and frequency	✓	✓	✓	✓
Protective factors	Fluoride usage	✓	✓	✓	✓
Social factors	• Low familial SES[c]	✓	✓		
	• Immigrant background	✓			
Environmental factors	Familial caries experience	✓	✓		
Health	• Medication		✓		
	• Systemic disease		✓	✓	✓
Program feature	User adjustment possible	✓		✓	✓
Assessment method		reasoning-based	reasoning-based	algorithm-based	algorithm-based
Caries risk prediction		1–3[d]	1–4[e]	1–5[f]	1–3[d]

[a]AAPD CAT (American Academy of Pediatric Dentistry caries risk assessment tool) (113)
[b]CAMBRA, (Caries Management by Risk Assessment) (109, 111), Cariogram (101), R2, (108, 115)
[c]SES, socioeconomic status; [d]Low, moderate, high risk; [e]Low, moderate, high, very high risk; [f]Very low, low, medium, high, very high risk

The Featherstone et al. study compared CRA methods in preschool children with 13 hypothetical patients and found similar results for Cariogram and

CAMBRA, with the AAPD CAT tending to estimate higher risk categories (57). Agouropoulos et al. validated different CRA methods in preschool children in areas of high caries prevalence and found higher validity for Cariogram and CAMBRA than the AAPD CAT, but also concluded that the accuracy was limited (116). These four CRA tools are of two types, reasoning-based (CAMBRA and CAT) and algorithm-based (Cariogram and R2). Reasoning-based tools are preferable in pedagogical use, while algorithm-based tools, which compile risk factors and risk indicators, can provide a more refined risk calculation (107).

Table 3. Sensitivity and specificity of four caries risk assessment tools for preschool children.

CRA tool	Sensitivity	Specificity
[a]AAPD CAT with social factors (107)	100	4
[a]AAPD CAT without social factors (107)	99	4
[b]CAMBRA (107)	84	63
Cariogram (107)	65	79
Cariogram (103)	66	57
R2	Unpublished	Unpublished

[a]AAPD CAT, American Academy of Pediatric Dentistry Caries Risk-Assessment Tool;
[b]CAMBRA, Caries Management by Risk Assessment

1.8.2 KNOWLEDGE GAP

Today, we have good knowledge of the etiology of caries, what influences caries development, and how caries can be prevented; yet caries remains a major health problem in all developed and developing countries (9, 10, 12, 117, 118). The predictive ability of caries risk programs and models differ, however, presence of caries is a strong predictive factor. All known factors, oral, environmental, and social, must be included and weighed to make the most accurate assessment possible. On the community level, inequality in dental health occurs, and this is closely linked to the socioeconomic status of the environment and social determinants of health. This is an indication of the importance of research in this field (18). In a population with low experience of dental caries there are still children exposed to risk factors who develop caries in early ages; these children are also important to find. Previous studies have demonstrated the importance of locating not only causal factors but also coexisting factors from environmental and social factors (15, 44, 62).

Preventive treatment should prevent undesirable disease development. Primary and secondary preventive treatment should prevent development or further development of caries and reduce the effect of risk factors.

2 AIMS

The general aim of this thesis was to determine caries risk factors and risk indicators for caries in preschool children through analyses of oral, environmental, and social factors.

The specific aims were to:

I. Evaluate possible risk factors associated with early colonization of mutans streptococci (MS) in 1-year-old children.

II. Identify possible caries risk factors among 1-year-olds and examine them clinically for dentin caries at the age of 3 years.

III. Identify caries risk factors and indicators in 1-year-olds that predict dentin caries at the age of 6 and analyze the sensitivity and specificity of a caries risk assessment by dental professionals in relation to caries prevalence at age 6.

IV. Investigate the predictive ability of an individual caries risk assessment of oral factors that includes social factors compared with caries outcome in preschool children by analyzing various models that incorporate both oral and social factors.

3 PATIENTS AND METHODS

3.1 STUDY DESIGNS

Paper I was a cross-sectional, retrospective study that retrieved data from the dental records of 1-year-olds enrolled in the Östergötland County PDS. Papers II and III were prospective studies, using data retrieved from the dental records of eligible members in the Paper I cohort at ages 1 and 3 (Paper II) and ages 1 and 3–6 (Paper III). Paper IV was a registry-based, retrospective study that identified 6-year-olds enrolled in the Kalmar County PDS; data from their dental visits between ages 3 and 6 years were retrieved.

3.2 STUDY POPULATION

The study cohort in Papers I–III comprised children enrolled at the PDS in Östergötland County (Figure 6). Paper I comprised all 1-year-old children born in 2001–2010 who had made their routine 1-year dental visit. The study cohort in Paper II included the children in Paper I who were born 2001–2009 and who had visited a PDS clinic at age 1 year and again at age 3 years. The study cohort in Paper III included eligible children from the Paper II cohort who had visited a PDS clinic at age 1 year, and ages 3–6 years.

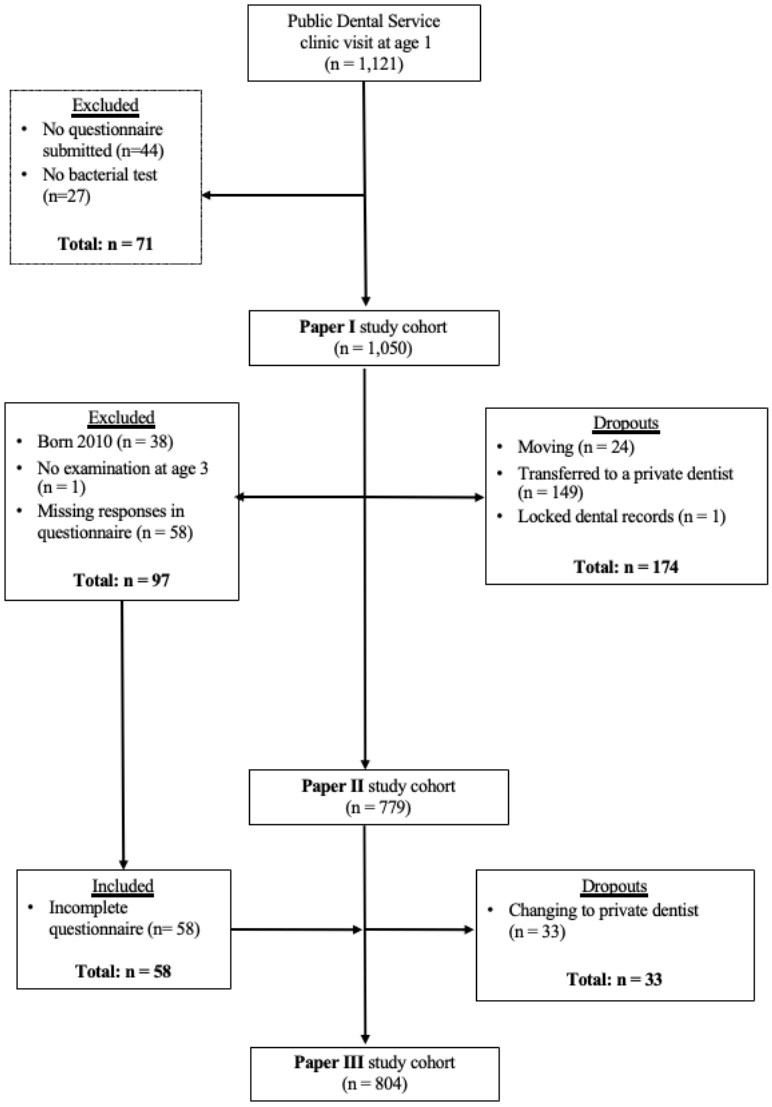


Figure 6. Included and excluded children in Papers I–III.

The study cohort in Paper IV comprised children born in 2012 who were enrolled in the PDS in Kalmar County and been assessed for caries risk at age 6. Examination code had to be available in the SkaPa (Figure 7). Data from dental visits at ages 3, 4, and 5 years were retrieved. Data for ages 4 and 5 were pooled.

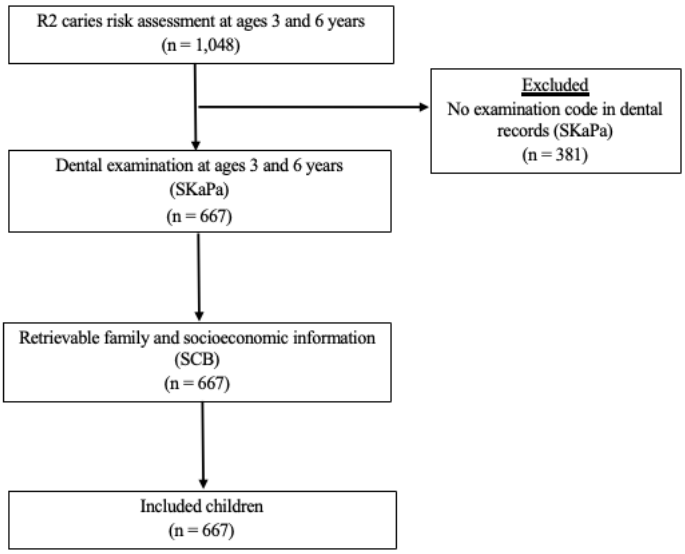


Figure 7. Numbers of included and excluded children, reason for exclusion, and registries from which data were retrieved in Paper IV. R2 was the caries risk assessment tool used, Examination codes and caries prevalence in the study cohort were retrieved from the Swedish Quality Register of Caries and Periodontitis (SKaPa). Statistics Sweden (SCB) provided data on social factors.

3.3 METHODS

3.3.1 OVERVIEW

Table 4 presents a compilation of the methods in Papers I–III.

Table 4. Methods in Papers I–III.

Methods	Paper I	Paper II	Paper III
Questionnaire at age 1 year	✓	✓	✓
Bacterial sample at age 1 year	✓	✓	✓
Caries risk assessment at age 1 year		✓	✓
Caries status at age 3 years		✓	✓
Caries risk assessment at age 3 years			✓
Caries status at age 6 years			✓

3.3.2 QUESTIONNAIRE

Each caregiver received a questionnaire before the first visit at age 1. The questionnaire concerned the child's health and medication status, drinking and eating behavior, and oral hygiene habits (Papers I–III; Table 5).

Table 5. Questionnaire items and variables recorded at age 1 year. Answers in bold text were considered to indicate a risk.

Item	Variable	Answer
Does the child have siblings?	*Siblings*	**Yes**/No
Have any siblings had caries?	*Siblings with caries*	**Yes**/No
Does the child eat or drink anything except water at night?	*Night meals*	**Yes**/No
Is the child still breastfed?	*Breastfeeding*	**Yes**/No
Does the child have any illnesses or diseases?	*Disease*	**Yes**/No
Does the child take any medication regularly?	*Medication*	**Yes**/No
Does the child drink anything except water between meals?	*Beverages other than water between meal*	**Yes**/No
Do you brush the child's teeth?	*No tooth brushing*	Yes/**No**
How many teeth are visible?	*Number of teeth*	Numbers

3.3.3 BACTERIAL SAMPLE

At the routine visit at age 1 year, a bacterial sample was collected. A bacterial count for mutans streptococci was measured using Dentocult Strip Mutans® (Orion Diagnostica, Espoo, Finland). Plaque at the gingival margin was collected with a Quick-Stick® (Dentsolv AB, Saltsjö-Boo, Sweden). After incubation, number of colony-forming units (CFU) on the test strip was determined, compared with the manufacturer's assay template and assigned a score of 0–3 (Table 6, Figure 8; Papers I–III). If the bacterial test was positive, indicating the presence of mutans streptococci, the parents of the children received information and advice for reducing the negative effects of bacteria.

Table 6. Bacterial sample scores for the mutans streptococci count (CFU/ml) on the test strip according to the manufacturer's assay template[a].

Score	CFU/ml
0	$< 10^4$
1	$10^4 – 10^5$
2	$10^5 – 10^6$
3	$> 10^6$

[a]Orion Diagnostica

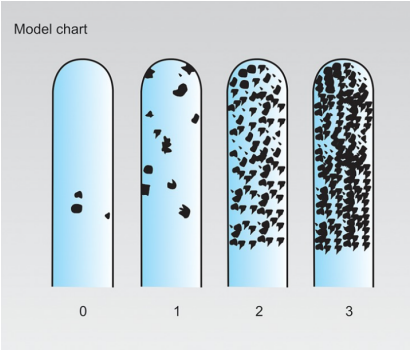


Figure 8. Illustration of the mutans streptococci scores according to the manufacturer's (Orion Diagnostic) assay template (119).

3.3.4 CARIES STATUS

Clinical dental examinations were made between 3 and 6 years of age, in a dental chair and using a mirror and a dental explorer. Caries status was

determined as numbers of decayed manifest teeth, extracted teeth due to caries, filled teeth, and affected primary teeth (21). This thesis, analyses caries experience as deft. Caries status was retrieved from clinical dental records (Papers II, III) and from SKaPa (Paper IV).

3.3.5 CLASSIFICATION OF CARIES RISK ASSESSMENT

A caries risk assessment was made at the 1-year visit. The caries risk assessment was based on the questionnaire responses and oral hygiene results from the intraoral inspection (Table 5). The outcome of the 1-year risk assessment was dichotomous, a 2-graded scale: “Low Risk” or “High Risk” (Papers II, III, Table 7). Risk was assessed manually.

The outcome of the 3-year risk assessment was a 4-graded scale: “No risk”, 0; “Low Risk”, 1; “Moderate risk”, 2; and “High Risk”, 3 (Paper III). Risk was assessed manually.

The outcome of the 3–5-year risk assessment was 3-graded: “Low Risk”, “Moderate Risk”, and “High Risk”. Risk was assessed with R2, an algorithm-based tool (Paper IV).

Table 7. Divisions of risk levels before analysis in this thesis. Caries Risk assessment was done at ages 1, 3, and 4–5 years.

Age at caries risk assessment (Years)	The thesis caries risk assessment levels for analysis				Paper
	Low risk		High risk		
1	Low risk		High risk		II
3	No risk	Low risk	Moderate risk	High risk	III
3	Low risk		Moderate risk	High risk	IV
4–5	Low risk		Moderate risk	High risk	IV

3.3.6 ENVIRONMENTAL FACTORS

Environmental factors (including family factors) were the questionnaire variables *Sibling with caries*, *Night meals,* and *Beverages other than water between meals* (Table 5).

3.3.7 WORKFLOW

Figure 9 illustrates the workflow of data collection from dental records and registries in Paper IV.

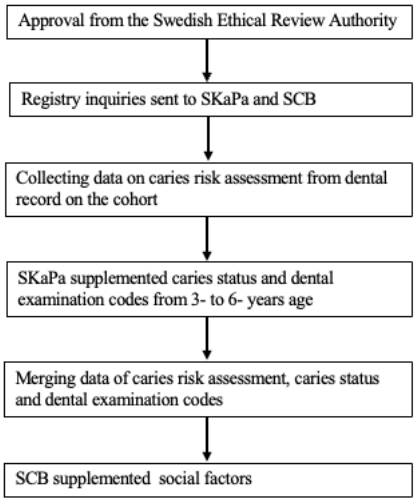


Figure 9. Workflow in Paper IV for retrieving data from the dental records and registries: SKaPa; the Swedish Quality Registry of Caries and Periodontitis; and SCB, Statistics Sweden.

3.3.8 SOCIAL FACTORS

The social factors retrieved from the SCB database in Paper IV are presented in Table 8. Social factors were collected 3, 4 and 5 years of age.

Table 8. Environmental, familial, and social factors retrieved for ages 3, 4–5, and 6 years (Paper IV).

Variables	Age (years)		
	3	4–5	6
Gender (boy/girl)	✓		
Oral factors			
Caries risk assessment[a]	✓	✓	
Caries prevalence (deft[b] > 0)	✓	✓	✓
Social factors			
Foreign background (non-Nordic country)[c]	✓		
Siblings (No siblings, ≥ 3 siblings, birth order)	✓		
Years in preschool (> 3 years)			✓
Residential area[d]	✓	✓	
Changing addresses (> 3 moves)			✓
Family situation[e]	✓	✓	
Parental ages at birth of child[f]	✓		
Level of parental education[g]	✓	✓	
Disposable family income[h]	✓	✓	

[a]Assessment outcome: "Low risk", "Moderate risk", and "High risk"; dichotomized for analysis: "Low Risk" or "High Risk"
[b]deft (decayed, extracted, filled, primary teeth)
[c]child born in a non-Nordic country, or one or both parents born in a non-Nordic country
[d]outside of an urban area, in an urban area, or in a central municipality
[e]living in a single-parent family, a 2-parent family, or some other family constellation (e.g., with other relatives, such as older siblings, grandparents)
[f]aged < 23 or > 39 years, > 22 and < 40 years.
[g]≤ 9 years, 10–12 years, or > 12 years of education
[h]disposable income under or above 60% of the Swedish median income, 2015–2017: SEK 143,200; SEK 146,000; and SEK 149,600

3.3.9 CARIES RISK MODELS

Several caries risk models based on the collected data, were designed and tested. The models included oral, environmental, and social factors that constituted possible risk factors and could increase the predictive ability of the caries risk assessments retrieved from the dental records. Models were designed for the 1-, 3-, and 4–5-year age groups (Papers II–IV). The predictive models in Papers II and III comprised bacterial tests and various combinations of environmental factors at age 1 (models a_1-i_1).

In Paper IV, designed predictive models based on R2 caries risk assessments at ages 3 and 4–5 years, which were augmented with various constellations of

social factors to see what combination gave the clearest predictability, models from Paper IV are j_3-m_3, and $n_{4\text{-}5}$, and $o_{4\text{-}5}$.

3.4 PRIMARY OUTCOMES

The primary outcomes were caries status at age 3 years (Paper II) and 6 years (Papers III, IV).

3.5 STATISTICS

3.5.1 STATISTICAL PREPARATION

All variables were dichotomized before analysis (Papers I–IV).

Papers I–III pooled high and very high MS scores (2–3) into "*High MS Score*".

Paper IV analyzed data in two age groups: At 3 years of age, data were noted as 3, i.e., deft at age 3 years was written $deft_3$. At 4 and 5 years of age, data were pooled and noted as 4–5, i.e., $deft_{4–5}$.

Social factors were grouped, and responses dichotomized (Paper IV; Table 8).

3.5.2 STATISTICAL ANALYSES

The papers in this thesis used the following programs in statistical analysis: *Paper I*, Stata/MP (version 12.1; StataCorp LP, Collage Station, TX, USA); *Paper II*, Stata/MP (version 13); *Paper III*, for ROC curve analyses, MedCalc (MedCalc Statistical Software version 19.2.1, MedCal Software Ltd, Ostend, Belgium) and for all other analyses, Statistica (Statistica v.12 StatSoft Inc., Tulsa, Oklahoma, USA); and *Paper IV*, Stata Release (version 17.0; SE-Standard Edition, StataCorp LLC). Statistical analysis in the thesis Stata Release (version 18.0; SE-Standard Edition, StataCorp LLC) was used.

p-values < 0.05 were considered significant.

Student's *t*-test. Compared groups of continuous variables: age and number of teeth (Paper I).

chi-square test. Compared groups of categorical variables: questionnaire responses and bacterial findings. The test was also used to determine the

association of variables with *Presence of MS* or *High MS Score* (Paper I). Comparisons included children in Papers II–IV who had dropped out.

Simple logistic regression. Detected 1-year visit variables that were associated with caries prevalence at age 3 (deft > 0; Paper II) and age 6 (Paper III). The regression also detected associations between caries status at age 6 and independent variables (Paper IV).

Multiple logistic regression. Identified factors associated with "*Prevalence of MS", "High MS Score*" (Paper I) and caries status (deft>0) at ages 3 and 6 years (Papers II–IV).

Receiver operating characteristic and area under the ROC curve. Estimated the predictive ability of the risk models for predicting caries status (deft>0; Papers II–IV). The ROC is a probability curve and shows the trade-off between sensitivity (True positive range) and specificity (1–False positive range). AUC tell us the degree of separability and how well the model is capable of distinguishing between individuals with caries or no caries (healthy individuals). Levels above 0.5 in AUC are positive values but need to be higher for the model or test to be considered useful.

DeLong test. Compared ROC curves in a pairwise comparison *(i)* between the models and *(ii)* within age groups (Papers III, IV).

Sensitivity and specificity. Determined the model´s ability to find the proportion with actual caries (True Positive/[True Positive+False Negative]; sensitivity) and the proportion with no actual caries (True Negative/[True Negative+False Positive]; specificity) (Papers II–IV).

Positive and negative predictive values (PPV and NPV). Determined the ratio of patients truly diagnosed with caries to all who had positive test results **(**True Positive/[True Positive+False Positive]; PPV) and the ratio of patients truly diagnosed with no caries to all who had negative test results (True Negative/[True Negative+False Negative]; NPV) (Papers II–IV).

PPV and NPV values are directly related to the prevalence of caries in the population that is being tested.

4 RESULTS

4.1 CARIES EXPERIENCE

At age 3 years, caries status (deft > 0) was 2.6%–6 % (Papers II–IV). At age 6, caries status (deft > 0) was 16% (Paper III) and 25% (Paper IV).

4.2 ORAL FACTORS

4.2.1 MUTANS STREPTOCOCCI

At age 1 year, *presence of mutans streptococci* was 27%–31% (Papers I–III). Multiregression analyses investigated factors associated with *presence of mutans streptococci* were performed (Table 9; Paper I).

Table 9. Multiregression analysis of oral and environmental factors associated with presence of mutans streptococci in 1-year-old children (n= 1,038; Paper I).

Variable	OR	95% CI	*p*-value
Siblings with caries[a]			
Yes	1.60	1.05–2.45	**0.028**
No		1	
Night meal			
Yes	0.97	0.70–1.34	0.85
No		1	
Breastfed			
Yes	1.21	0.76–1.92	0.42
No		1	
Disease			
Yes	0.78	0.30–2.00	0.60
No		1	
Medication			
Yes	1.64	0.54–4.99	0.38
No		1	
Beverages other than water between meals			
Yes	1.75	1.30-2.37	**< 0.001**
No		1	
> 0 erupted teeth			
Yes	7.68	0.95–62.34	0.056
No		1	
Tooth brushing			
Yes		1	
No	1.62	0.88–2.99	0.12

[a]Included all children; children without siblings were grouped with the non-responders.
OR, odds ratio; CI, confidence interval
p-values < 0.05 were considered significant (bold text)

A *High MS Score* indicated an association with the variable *Beverage other than water between meals* (OR 1.9; 95% CI; 1.16–3.14; $p = 0.011$; Paper I) in multiple regression analyses. Analysis of the children with siblings (n=576) showed association to *Siblings with caries* (Chi^2 p=0.01).

4.2.2 MUTANS STREPTOCOCCI AND CARIES

4.2.2.1 FOLLOW-UP AT AGE 3

Simple regression analyses in Papers II and III showed that *Presence of MS* in 1-year-old children was associated with caries at age 3 years (OR 3.2; 95% CI; 1.3–7.9; Paper II) and (OR 3.5; 95% CI 1.53–7.83; Paper III). Multiple regression analyses in Paper II showed that a *High MS Score* at 1 year was also associated with caries at 3 years (OR 3.4; 95% CI 1.1–10.8) while simple regression analyses in Paper III showed the same (OR 6.9; 95% CI 2.94–16.40).

4.2.2.2 FOLLOW-UP AT AGE 6

Paper III showed that *Presence of MS* in 1-year-old children was associated with caries at age 6 in simple regression analyses (OR 1.8; 95% CI 1.22–2.64), as was a *High MS Score* (OR 2.6; 95% CI; 1.46–4.52).

4.3 ENVIRONMENTAL FACTORS AND CARIES

4.3.1 FOLLOW-UP AT AGE 3

At age 1 year, factors that showed an association with caries at 3 years of age were *beverages other than water between meals* (OR 7.1; 95% CI 2.5–20.5), *sibling with caries* (OR 4.8; 95% CI 1.8-13.3), and *night meals* (OR 3.0; 95% CI 1.1–8.1) in multiple regression analyses (Paper II).

Estimated sensitivity for a factor associated with caries at age 3 were *beverages other than water between meals*, 75%; *siblings with caries*, 40%; and *night meals*, 60% (Paper II). The Positive Predictive Value (PPVs) were *beverages other than water between meals*, 7.3%; *siblings with caries*, 9.0%; and *night meals*, 5.0 % (Paper II). Those with positive findings had caries at follow-up.

4.3.2 FOLLOW-UP AT AGE 6 (PAPER III)

In Paper III, multiple regression analyses showed that *beverages other than water between meals* at age 1 year was associated with caries at age 6 years (OR 1.9; 95% CI 1.26–2.82). *Night meals* at age 1 were associated with dentin

caries at age 6 (OR 1.9; 95% CI 1.27–2.83). *Siblings with caries* at age 1 were associated with dentin caries at age 6 (OR 2.1;95% CI;1.19–3.80). Estimated sensitivity for *beverages other than water between meals* was 44% and for *night meals*, 47%. PPVs confirmed that 25% of the children with positive findings for *beverages other than water between meals* had presence of caries; 28%, *siblings with caries*; and 23%, *night meals*.

4.4 SOCIAL FACTORS AND CARIES

4.4.1 SOCIAL STATUS AT AGES 3 AND 4–5 YEARS

Table 10 shows that, at the 3-year visit, the social factors associated with caries were *foreign background*, *low economy*, *low parental education level, single-parent family*, and *≥ 3 siblings*. *Foreign background*, *single-parent family*, *low economy,* and *low parental education level* were less important at 4–5 years while ≥3 siblings remained similar to at age 3 years.

Table 10. Simple regression analyses of social factors at ages 3 and 4–5 years and their association with deft > 0 at age 6 (Paper IV; simple regression analyses).

Social factor	Age 3 years			Age 4–5 years		
	OR	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**
Foreign background[a]						
Yes	4.6	3.00–7.05	**< 0.001**	4.3	2.49–7.45	**< 0.001**
No	1			1		
Low economy[b]						
Yes	2.8	1.89–4.22	**< 0.001**	2.2	1.33–3.62	**0.002**
No	1			1		
Low paternal education level[c]						
Yes	2.4	1.49–3.96	**< 0.001**	2.4	1.30–4.44	**0.005**
No	1			1		
Low maternal education level						
Yes	2.8	1.60–4.78	**< 0.001**	2.7	1.25–5.64	**0.011**
No	1			1		
Single-parent family						
Yes	2.2	1.19–3.73	**0.01**	1.5	0.82–2.87	0.185
No				1		
≥ 3 siblings						
Yes	1.7	1.14–2.59	**0.01**	1.7	1.01–2.82	**0.044**
No	1			1		

OR, odds ratio; CI, Confidence Interval
p-values < 0.05 were considered significant
[a]foreign background (child or one or both parents born in a non-Nordic country)
[b]under 60% of the Swedish median income
[c]≤ 9 years of education

4.5 AGE GROUP CARIES RISK ASSESSMENTS

4.5.1 AGE 1 YEAR

Paper II assessed 34 (4.4%) of the 1-year-old children as having a high risk of developing caries in coming years, and Paper III, 39 (4.9%) of the children. A high caries risk at age 1 was associated with caries at age 3 in both Papers (II and III; thesis Table 11). The predictive ability of the caries risk assessment at age 1 year, having high risk for caries and caries at 3 years (deft > 0) was 58%

of the individuals in Paper II and 62% in Paper III (Table 13); that is, 58% and 62% of the cohorts could be correctly classified with caries or no caries.

Risk assessment sensitivity at age 1 year was 21% in Paper II and 28% in Paper III. Thus, assessment correctly classified 21% and 28% of the children with risk of caries and caries at 3 years age. Specificity of 96% showed that 96% of the 1-year-olds assessed as having no risk of caries had no caries at age 3 (Papers II, III). PPVs for children with a high caries risk at age 1 and a deft > 0 at age 3 were 12% in Paper II and 18% in Paper III, which means that 12% and 18% of those assessed with a high risk of caries had developed caries.

Table 11. Association of a high risk of caries at baseline with a Δ deft > 0 at follow-up. At age 1 year, deft = 0 in all children.

Age[a] (years)	Caries risk	Age at follow-up (Δ deft > 0)	n	OR	95% CI	*p*-value	Paper
1	High Risk[b]	3	4	6.0	2.03–20.74	**0.002**	II
	Low Risk	3	16	1			
1	High Risk[b]	3	7	9.0	3.53–23.27	**< 0.001**	III
	Low Risk	3	18	1			
1	High Risk[b]	6	18	5.2	2.66–9.98	**< 0.001**	III
	Low Risk	6	109	1			
3	High Risk[c]	6	16	17.6	6.73–45.95	**< 0.001**	III
	Low Risk	6	103	1			
3	High Risk[d]	4–5	14	7.4	3.37–16.31	**< 0.001**	IV
	Low Risk	4–5	23	1			
3	High Risk[d]	6	22	5.9	2.91–12.14	**< 0.001**	IV
	Low Risk	6	60	1			
4–5	High Risk[d]	6	40	8.4	4.82–s14.54	**< 0.001**	IV
	Low Risk	6	38	1			

OR, odds ratio; CI, Confidence Interval; n = number of children; Δ deft, the increase in deft related to baseline; *p*-values < 0.05 were considered significant; statistical analysis was done using simple regression analyses

[a]Baseline age in years at caries risk assessment.

[b]Caries risk assessment at age 1 year with one of two outcomes: "Low risk" or "High Risk".

[c]Manual caries risk assessment with four outcomes at age 3 and pooled into two groups: "Low risk" and "High Risk".

[d]Algorithm-based caries risk assessment with three outcomes at 3 and 4–5 years of age and pooled into two groups: "Low Risk" and "High Risk".

Table 12. Overview of designed models and the included combinations of oral, environmental and social factors at 1, 3 and 4-5 years of age. Age in subscript.

Variables	**Designed caries risk assessment models**														
	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1	i_1	j_3	k_3	l_3	m_3	n_{4-5}	o_{4-5}
Oral factors															
High-Risk at age 3 years										√	√	√	√		
High-Risk at age 4–5														√	√
Bacterial test															
Presence of MS		√			√			√							
High MS score[a]			√			√			√						
Environmental factors															
Siblings with caries	√	√	√	√	√	√	√	√	√						
Night meal	√	√	√	√	√	√	√	√	√						
Beverage other than water between meals	√	√	√	√	√	√	√	√	√						
Social factors															
Foreign background[b]											√		√	√	√
≥3 siblings										√	√	√	√	√	√
Single parent family										√	√	√	√		√
Low paternal education level[c]										√		√		√	√
Low maternal education level[c]										√		√			√

[a]having >10^5CFU/ml

[b]foreign background (child or one or both parents born in a non-Nordic country)

[c]having ≤9 years of education

Table 13. Predictive ability (AUC) of caries risk assessment in retrieved dental records and best-fitting caries risk models for various ages (Papers II–IV). Explanation of included factors in different models see Table 12.

Age at risk assessment (years)	Age at deft > 0 (years)	Risk assessment (AUC)	Caries risk model (AUC)	Model named	Paper
1	3	0.58	0.80	a_1	II
1	3	0.58	0.80	b_1	II
1	3	0.58	0.80	c_1	II
1	3	0.62	0.78	d_1	III
1	3	0.62	0.78	e_1	III
1	3	0.62	0.79	f_1	III
1	6	0.58	0.65	g_1	III
1	6	0.58	0.66	h_1	III
1	6	0.58	0.65	i_1	III
3	4–5	0.69	0.78	j_3	IV
3	4–5	0.69	0.78	k_3	IV
3	6	0.63	0.70	l_3	IV
3	6	0.63	0.70	m_3	IV
4–5	6	0.78	0.82	n_{4-5}	IV
4–5	6	0.78	0.82	o_{4-5}	IV

AUC, area under the receiver operating characteristic curve; deft, decayed, extracted, and filled primary teeth.

4.5.2 AGE 3 YEARS

Paper III assessed caries risk manually through analyses of family, medical, and dental factors. Risk assessment in Paper IV used an algorithm-based tool, assessing caries status (excluding occlusal surfaces), dietary habits, oral hygiene, and medical risk. At age 3, 22 (3%) of the children in Paper III and 37 (6%) in Paper IV were assessed with high caries risk. Simple regression analyses showed that children with a high risk of caries at age 3 were associated with caries *(i)* at ages 4–5 (Paper IV; thesis Table 14) and *(ii)* at age 6 (Papers III, IV; thesis Table 14). The predictive ability of caries risk assessment at age 3 and a deft > 0 at age 6 was 68% in Paper III and 63% in Paper IV (Table 13, Figure 10), which means that 68% of the children were correctly classified by the caries risk assessment in Paper III. The predictive ability of the caries risk assessment to find the proportion of those who would develop caries, that is, sensitivity, was 41% in Paper III. The PPV showed that 52% (Paper III) and 70% (Paper IV) of the children with a positive test would develop caries. The caries risk assessment at age 3 showed *(i)* a sensitivity of 43% and a specificity of 95% at age 4–5 years and *(ii)* a sensitivity of 30% and a specificity of 96% at age 6 (Paper IV).

Table 14: Association of high caries risk at baseline with deft > 0 at follow-up.

Age[a]	Caries risk	Age at deft > 0	n	OR	95% CI	*p*-value	Paper
3	High Risk[b]	6	20	63.0	14.54–273.76	**< 0.001**	III
	Low Risk	6	107	1			
3	High Risk[c]	4–5	18	14.5	6.48–29.62	**< 0.001**	IV
	Low Risk	4–5	27	1			
3	High Risk[c]	6	26	9.6	4.48–20.46	**< 0.001**	IV
	Low Risk	6	60	1			
4–5	High Risk[c]	6	67	36.7	18.47–72.95	**< 0.001**	IV
	Low Risk	6	47				

OR, odds ratio; CI, Confidence Interval; n = number of children; *p*-values < 0.05 were considered significant; simple regression analyses. deft, decayed, extracted, and filled primary teeth.

[a]Age in years at caries risk assessment

[b]Manual caries risk assessment with four outcomes at age 3 and pooled into two groups: "Low risk" and "High Risk".

[c]Algorithm-based caries risk assessment with three outcomes at 3 and 4–5 years of age and pooled into two groups: "Low Risk" and "High Risk".

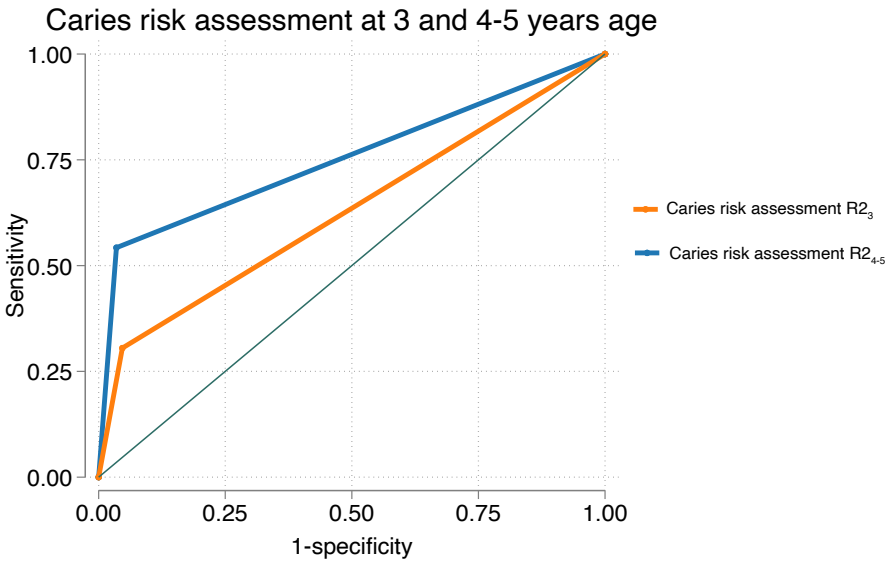


Figure 10. Caries risk assessment at ages 3 and 4–5 years with deft > 0 at 6 years age. Receiver Operating Characteristic (ROC) curve, depicting the predictive capability of the caries risk assessment at ages 3 and 4–5. The area under the ROC curve in caries risk assessment $R2_3$ is 0.63, and in caries risk assessment $R2_{4–5}$, 0.78 (Paper IV).

4.5.3 AGE 4–5 YEARS

At ages 4–5 years, 79 (13%) children were assessed with a high risk of caries (Paper IV). A high caries risk at age 4–5 was associated with caries increment, a higher deft at age 6 (Paper IV; thesis Table 11). The predictive ability of caries risk assessment was 78%, a measure of how well the caries risk assessment correctly identified high caries risk (Figure 10). Caries risk assessment had a sensitivity of 59%, a specificity of 96% (Paper IV), and a PPV of 85% for caries risk at ages 4–5 years with a deft > 0 at age 6.

The predictive ability of caries risk assessment by R2 increased with age and when risk was assessed closer in time to the next follow-up, shown by higher AUC (Figure 10).

4.6 CARIES RISK ASSESSMENT AND CARIES DEVELOPMENT

4.6.1 CARIES RISK ASSESSMENT AND CARIES FREE

Paper III found an association between caries-free children with a high risk of caries at age 3 years and caries development at age 6 (OR 5.0; 95% CI 2.08–12.03). Caries risk assessment was supplemented with familial, medical, and dental factors. In contrast, Paper IV found no association between caries-free children with a high risk of caries at age 3 and caries development at ages 4–5 (OR 2.0; 95% CI 0.76–5.16) or at age 6 (OR 1.6; 95% CI 0.72–3.41). Caries risk assessment was supplemented with caries status (occlusal caries excluded), dietary habits, oral hygiene, medical risk.

4.6.2 CARIES RISK ASSESSMENT AND CARIES INCREMENT

Children with a high risk of caries were associated with caries increment at next follow-up (Papers III, IV; thesis Table 11). Sensitivity increased when risk was assessed at higher ages (Paper IV; thesis Table 15). Of the children with a low risk of caries at age 3, 10% developed caries at age 4–5 and 20% at age 6. Children with assessed having low risk of caries at 3 years of age still are caries free at age 6 compared to those who developed caries (Chi^2 $p < 0.001$; Paper IV).

Table 15. Sensitivity, specificity, and predictive ability (AUC) of high caries risk at baseline with deft > 0 at follow-up (Paper IV).

Age at caries risk assessment[a] (years)	Age with Δ deft > 0 (years)	Sensitivity (%)	Specificity (%)	AUC
3	4–5	38	92	0.65
3	6	27	94	0.61
4–5	6	51	89	0.70

AUC, area under the receiver operating characteristic curve. deft, decayed, extracted, and filled primary teeth.
[a]Baseline

4.7 CARIES RISK MODELS

The first models designed attempted to predict caries at 3 and 6 years of age based on data when the child was 1 year old (Papers II and III). The first designed models (a_1-c_1) in Paper II were based on the bacterial test and the questionnaire responses of the guardians at the 1-year visit of the children who had developed a deft > 0 at age 3 (Table 12). Model a_1 included three environmental factors: *siblings with caries, night meals, beverages other than water between meals* and showed a predictive ability of 0.80 (Paper II; thesis Tables 12 and 13). In model b_1, the oral factor *presence of MS* was supplemented to model a_1, and in model c_1 *high MS Score* was supplemented to model a_1 the predictive ability was still 0.80 (Paper II) (Tables 12 and 13).

Paper III tested the models, (d_1-f_1), (age 1 year and deft > 0 at age 3 years) with the same environmental variables as in the previous models (a_1-c_1) (Table 12). Predictive ability was 0.78 for the three environmental factors (Paper III; thesis Table 13). Inclusion of *presence of MS* at age 1 had no effect on predictive ability, but including *high MS Score* increase the predictive ability (0.79) (Table 13). In the Paper III cohort, different models were tested (g_1-i_1), this time for use with data collected at the 1-year visit of children who had developed deft > 0 at age 6; the models included bacterial test and three environmental factors: *night meals, beverages other than water between meals,* and *sibling with caries* (Table 12). With the *presence of MS* included, the model had a predictive ability of 0.66 (AUC 0.66); exclusion of bacterial test had a harmless effect on predictive ability (Paper III; thesis Table 13).
In Paper IV, attempted to design models that would predict caries at ages 4–5 and at 6 when the child was 3 years old (j_3-m_3) and 4–5 years old ($n_{4\text{-}5}$ and $o_{4\text{-}5}$) (Figure 11;thesis Tables 12 and 13). Caries risk assessment at these ages was done using R2, an algorithm-based program. Adding social factors, including on family dynamics and socioeconomic aspects, to the caries risk assessment increased predictive ability for deft > 0 at age 6. The model l_3, for 3-year-olds were based on the R2 caries risk assessment at age 3 and these factors: *≥ 3 siblings*, *living in single-parent family,* and *low parental education level* (Tables 12 and 13). The caries risk assessment alone had a predictive ability of 63%; when the social factors were combined with the risk assessment, predictive ability for deft > 0 at age 6 increased 7%, to 70% (AUC 0.70; Paper IV; thesis Figure 11; thesis Table 13). A similar model, used with an R2 caries risk assessment at ages 4–5 years, increased predictive ability for caries at age 6 by 4%, to 82% (AUC 0.82) (Table 12 and 13). This model ($n_{4\text{-}5}$) was combined with these social factors: *foreign background*, *≥ 3 siblings*, and *low*

paternal educational level (Paper IV; thesis Figure 11, thesis Tables 12 and 13).

Social factors improved the predictive ability of the models to a greater extent at age 3 than at ages 4–5 years. In both age groups, model sensitivity was higher, and specificity lower compared to using the caries risk assessment alone (Paper IV; thesis Table 16).

Table 16. Sensitivity and specificity of the three risk models at ages 3 and 4–5 years for deft > 0 at age 6, derived from ROC curves in Figure 11 (Paper IV).

Model	Sensitivity	Specificity
[a]l_3	66	73
[b]m_3	63	72
[c]$n_{4–5}$	73	83

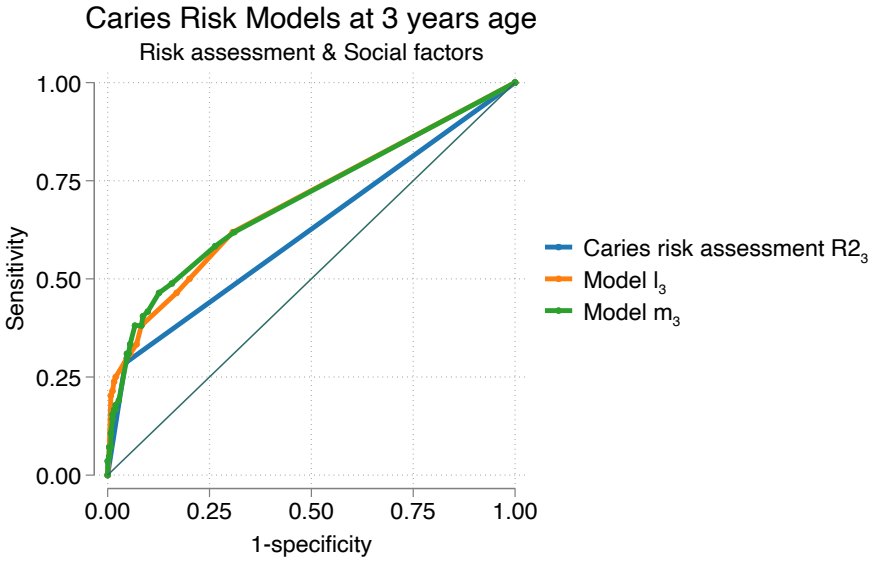
ROC, receiver operating characteristic

[a]includes R2 caries risk assessment and these social factors: *foreign background*, *≥3 siblings,* and *living in a single-parent family*.

[b]includes R2 caries risk assessment and these social factors: *≥3 siblings, living in a single-parent family*, and *low parental educational level.*

[c]includes R2 caries risk assessment and these social factors: *foreign background, ≥3 siblings*, and *low paternal educational level*.

a



b

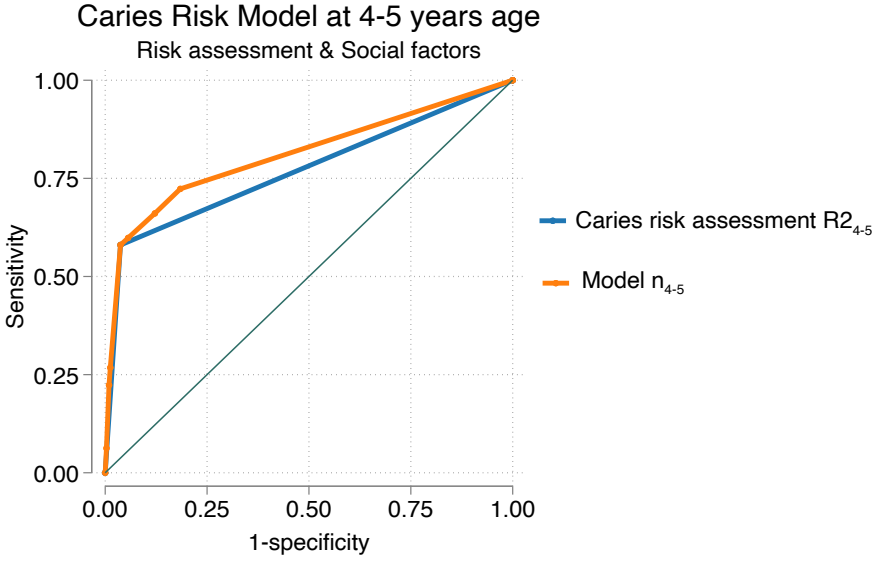


Figure 11 a-b. Receiver operating characteristic curve showing the predictive ability of three caries risk models for 3-year-olds and two for 4–5-year-olds. The models take into account caries risk assessment and social factors for children with deft > 0 at age 6 and are the models that best predict caries risk.

(a) Caries risk assessment R2 at age 3

Model l_3: based on the caries risk assessment R2 and these social factors: *foreign background*, ≥ *3 siblings*, and *living in a single-parent family*; Model m_3: based on the caries risk assessment R2 and these social factors: ≥ *3 siblings*, *living in a single-parent family*, and *low familial educational levels*.

(b) Caries risk assessment R2 at ages 4–5 years
Model $n_{4–5}$: based on the risk assessment R2, and these social factors: *foreign background*, ≥ *3 siblings*, and *low paternal educational level*.

The predictive ability (AUC) of three caries risk models was higher than the clinical caries risk assessments alone in Papers II–IV (Table 13).

4.8 DROPOUTS AND EXCLUDED CHILDREN

4.8.1 PAPER I

The 1,121 children who visited the Östergötland County PDS clinics in 2001–2010 for their 1-year visit were initially selected for the Paper I study cohort. Of these, 44 were excluded due to an incomplete questionnaire and 27, due to a missing bacterial sample (Figure 6), a total of 71 (6%). The study cohort comprised 1,050 1-year-olds.

4.8.2 PAPER II

The 1,050 children who visited the Östergötland County PDS clinics in 2001–2009 for their 1-year visit, essentially the same cohort in Paper I except for those born in 2010, were selected for the Paper II study cohort. Of these, 174 (16%) dropped out due to moving from the district, switching to a private dentist at age 3 years, or locked dental records. Another 59 were excluded due to missing data and 38, not fulfilling other inclusion criteria, equaling 97 (9%) (Figure 6).

Only 1-year data for the dropouts and excluded children were analyzed. Differences between the study cohort and the group of dropouts and excluded children were significant for *prevalence of MS* (chi-square; $p < 0.001$) and *high MS Score* (chi-square: $p = 0.02$). These variables were higher in the study cohort.

4.8.3 PAPER III

The 1,050 children who visited the Östergötland County PDS clinics for their 1- and 3-year visits were selected for the Paper III study cohort. Of these 207 (18%) dropped out due to moving from the district, switching to a private dentist at age 3 years, or locked dental records. Another 38 were excluded due to a missing clinical examination and 1, due to missing data, equaling 39 (3%). Of the excluded children in Paper II, 58 were included in Paper III (Figure 6). The only significant difference between the group of dropouts and excluded children (from Papers II and III cohorts) and the Paper III study cohort was in the variable *beverages other than water between meals*, which was more common among the dropouts and excluded children (chi-square; $p = 0.005$).

4.8.4 PAPER IV

Dental information for the 1,048 children in the Kalmar County PDS who were initially selected for the Paper IV study cohort was retrieved from the SKaPa Registry. The children had been born in 2012 and assessed for caries risk at ages 3 and 6 years. Of this group, 381 (36%) were excluded due to a missing examination code (a documentation error) in the registry. Without the code, information on caries status was impossible to retrieve (Figure 7). However, dental records for the excluded children could be retrieved from County records, and analyses found no significant differences between the final study cohort (included children) and the group of excluded children in the R2 assessment of caries risk at age 3 (chi-square with Yates correction; $p = 0.39$).

5 DISCUSSION

This thesis focused on risk factors and risk indicators for caries in preschool children with the aim of increasing predictive ability in caries risk assessment.

MAIN FINDINGS

The major finding of this thesis is that combining environmental and social factors with the traditional oral risk factors used in clinical assessments of caries risk improves the predictive ability of the caries risk assessments in preschool children (Paper IV).

Other findings include those social indicators associated with caries status (such as, foreign background, low economy level, and living in a single parent family) are more important in 3-year-old children than in 4- or 5-year-old children. Caries risk assessments have limited durability over time (Paper IV).

This thesis found that *presence of MS did* not add to the predictive ability of caries risk models; thus, supplementing the caries risk assessment with anamnestic questions provides information of similar value to bacterial test findings (Papers II, III).

In everyday clinical practice, screening with bacterial samples is costly and time-consuming. Thus, the purpose of Paper I was to find coexisting factors with mutans streptococci that could replace bacterial screening. *Presence of MS* was dichotomized: presence or no presence of MS. Number of MS colonies (CFU) was grouped into four scores. We found that 7% of the children had a high score, in line with the Grindefjord et al. study (51). All parents of children with *presence of MS* received information and advice on how to limit the negative effects of bacteria with toothbrushing two times/day and reduce sweetened snacks. *Presence of MS*, however, could have influenced caries development in their child. The bacterial test might have a higher impact on parents as an educational instrument than mere numbers, being a visual representation of the importance of oral hygiene for their children.

One child in this thesis with no erupted teeth had *presence of MS*. This seems impossible since MS needs a tooth surface in order to colonize. For this reason, such a bacterial test should be repeated after a few months to confirm *presence of MS*. However, Florio also reported presence of mutans streptococci in children without teeth (49).

High levels of mutans streptococci at age 1 were associated with caries in multiple regression analyses at age 3, and *presence of MS* at age 1 was found to be associated with caries at age 6 in a multiple regression analysis. Despite this, inclusion of bacterial results in models for caries risk did not improve the predictive ability of the models. These findings suggest that *presence of MS* together with other risk factors does not improve prediction for caries in the risk models. Havsed had an interesting reflection, that the effect of including MS in prediction models could be overestimated, since testing has shown that caries can occur in the absence of MS (120).

The risk models designed for predicting caries in Paper II had a higher predictive ability when including the factors; *siblings with caries, night meals,* and *beverages other than water between meals* than the caries risk assessment. *Sibling with caries*, and dietary habits, *night meals,* and *beverages other than water between meals,* were signs of the family's lifestyle habits, which were considered to comprise caries risk factors. This illustrates the importance of collecting anamnestic information about the family's caries experience and dietary habits. This is in line with Tinanoff et al., who describe dietary habits and sugar consumption as risk factors, and Grieshaber, who found that caries in an older sibling increased the risk of caries in a younger sibling more than three times (5, 121).

Paper IV found that social indicators of importance were *foreign background, parental educational level, family situation*, and *low economic situation*, though low economic status had no effect on predictive ability in the caries risk models. The social indicator with the highest OR was *foreign background*. The information of the social situation existing in the life of a preschool child's environment influence the caries development of is valuable information to be used in caries risk assessment and predictive risk models. This agrees with other studies (60, 62, 122, 123). An interesting finding was that social indicators decreased in importance with increasing age. A young child is more vulnerable to its social environmental than an older child, and risk factors and risk indicators will change. This is in line with Anderson and discussed by Christian et al. (62, 123).

The Swedish social dental model, the PDS, encourages individuals to have regular dental examinations. Preventive care is well established in PDS routines. The PDS was initiated in 1938, with the aim of providing children in the community with an opportunity of acquiring good oral health (124). In 1957 the WHO determined that fluoride was the only cure for caries and the

best thing was to fluoridate the drinking water. In the end of the 50s different types of toothpastes with fluoride were developed to limit the decay of the enamel (125). The Swedish "Fluortant" (Fluoride lady) started in the 1960s with fluoride rinsing in school for children (126). Another Swedish idea was "lördagsgodis" (limiting candy consumption to Saturdays) (127). The tradition began as a health recommendation in 1959 following the government-funded Vipeholm experiments (127). These ideas, aiming to improve oral health and create the conditions for maintaining good oral health, are well established in Swedish society.

New citizens may find it difficult to adopt Swedish dental care routines and recommendations when they come from a different culture, have lived under different conditions, and lack information on dental health and available dental care resources. In Sweden, both parents work outside of the family and most Swedish children attend preschool from an early age, where regular meals are served and access to sugar is limited. In other cultures, this could be different. Not all women have a work to go to, and the children stay at home. In *a single-parent family*, the care of the child can be affected: moving back and forth between parental residences and parental disagreements on how to bring up the child can be added difficulties. *Parental education level* can affect how information is interpreted and transformed into knowledge that will improve the health of the family (128).

It may seem that the findings of caries-associated social indicators are instead coexisting factors and do not contribute to an increased predictive ability in a caries risk assessment model, this is important to analyze. Let's play with the thought that all children with caries have brown eyes. This does not mean that brown eyes are a risk indicator for caries. Thus, indicators that are found to be associated with caries must be evaluated in relation to the caries risk assessment to determine whether the indicators actually enhance the predictive ability of the caries risk assessment. In Paper IV, this was done by creating models that included data on social indicators to an already performed caries risk assessment. Still, data on oral factors are a prerequisite for making a caries risk assessment (57, 101).

This thesis highlights the importance of an overall assessment that includes oral, environmental, and social factors. No new risk factors were found; instead, the existing caries risk assessment tool was refined and further developed with known indicators that have been found to coexist in children with caries (44, 60). In this thesis, well-accepted indicators were combined

with R2, currently, the commonly used caries risk assessment method. The chosen indicators were retrieved from the SCB registry for each participating child. Different groups of social indicators were combined with the clinical caries risk assessment to form models that could be tested for caries prediction. The models designed for 3-year-olds in Paper IV (l_3 and m_3) had a similar sensitivity and specificity as Cariogram alone, with no bacterial test (Figure 11; Tables 3 and 15) (103, 107). The caries risk model for use with 4–5-year-olds ($n_{4–5}$) had higher sensitivity and specificity than Cariogram (Figure 11; Tables 3 and 15). These models, l_3, m_3 and $n_{4–5}$, have a lower sensitivity and a higher specificity as AAPD CAT (Tables 3 and 15) (107). Antunes and Featherstone both define tough caries as a multifactorial disease where all risk factors and risk indicators should be assessed at the same time (57, 91).

Overall, before analyses the variable responses in the Papers were dichotomized in "yes" or "no", as other research has previously done (62). When dichotomizing, some information is lost, and a less sensitive instrument is created. Paper IV dichotomized the factors and indicators through pooling after consulting other studies with similar caries risk factors and risk indicators. Caries risk factors and risk indicators with more than two levels would probably be able to provide a more refined, accurate risk assessment; however, so much data would make calculations complex and require software. One example would be to use an AI tool to further refine risk assessment. These are complicated questions, and whether AI is a viable method for improving caries risk assessment would be an interesting question for future research. Published studies have already used machine learning models to predict risk factors (129-131).

Children who were caries free at the caries risk assessment but who had developed caries at the follow-up are the children who are difficult to find using the prediction models, even though knowledge that tooth decay increases with age (23, 29). Paper III found that caries-free children assessed as having a high risk of caries were associated with a deft > 0 at the next follow-up. Paper IV observed the opposite; caries-free children with a high risk of caries were not associated with caries development at follow-up. This thesis has not studied interventions that public dentistry has carried out after caries risk assessment, or which interventions have been carried out at home to reduce the risk of caries.

Children with caries experience and assessed as having a high risk of caries were associated with further development of caries at follow-up in Papers III

and IV. This probably indicates that the presence of caries is a strong predictor of continued development of caries and is important when risk assessment is carried out agrees with Mejare and Twetman (97, 99). The thesis results can be interpreted in several ways: children who were caries-free and judged to be at high risk received preventive treatment that showed positive results at follow-up. In Paper III, the interpretation could be that the children received either did not receive preventive treatment or the preventive treatment did not have the intended effect. No analysis of the subsequent treatment given after caries risk assessment has been done in this thesis. However, when experience of caries is a factor in predictive models, the predictive ability of the model is lost and is rather a caries risk assessment model. This agrees with Hänsel (100).

Dividing assessed risk into more than 2 risk levels complicates the handling of the risk assessment. For children aged 0–3 years, any risk factor should be seriously considered since caries can have major consequences in a short time. To determine whether the risk is moderate or high is complicated, though risk factors affect the development of the disease differently. The AAPD CAT for children up to age 3 years adopted this approach and presents overall risk in two categories: low or high risk (113).

Results of caries risk assessments are commonly divided into 3 or 4 risk levels (5, 57, 101). Children at high risk are the ones to be identified, after an overall assessment. Before analysis in the thesis, new divisions of risk levels were made to further focus on children at high risk. Different groups were combined to create only two, for low and high risk, which was a development from the published papers (Papers II and III; Thesis Table 7).The Swedish National Board of Health and Welfare supports the theory of two risk groups (132).

Risk level “No Risk” (0) in Paper III was analyzed as no risk, and “Low Risk” was analyzed as “High Risk”. This might cause misunderstanding when explaining the weighting of risk assessment After publication of Paper III data on high risk groups have been re-analyzed for the thesis (Table 7).

Evaluations of caries risk assessment are rather complicated and have a paradox, as Twetman described (99). If high risk was assessed, and preventive treatment turned out well, with no caries developing at the follow-up, the conclusion is that the caries risk assessment was “incorrect” because caries, that is, the outcome, did not develop. In cases where caries does develop, the caries risk assessment is considered “correct”. This is confusing as there are no other established ways to follow up the caries risk assessment other than

presence of caries. This paradox makes it difficult to draw any conclusions about how well the caries risk assessment functions.

Including anamnestic questions about environmental factors in a caries risk model for children aged 1 year increased the predictive ability of the clinical caries risk assessment by 16% (Paper III). When the caries risk assessment was supplemented with indicators about family and social status in Paper IV, predictive ability increased in both 3 and 4–5-year-old children. In addition, the results show that certain indicators are more important for the 3-year-old child than for the slightly older child. This information is also important to consider when implementing caries risk programs. Social indicators have varying degrees of influence depending on the child's age. This is shown by the variation in ORs for different risk factors and risk indicators at different ages. When the child is young, it is important to include social indicators in a caries risk assessment. The results are in line with Anderson and Christian (62, 123). This may be obvious since a younger child is in a dependent position concerning its parents and the social environment. In contrast, Cariogram does not contain social or environmental indicators as these factors are expected to affect other oral risk factors and are thereby made visible (101).

In Paper III, various models were used to assess predictive ability of caries risk assessment. Family and environmental information acquired at the age 1-year visit was used in a caries risk model, which showed caries predictive ability being equal to caries risk assessments at age 3 and at age 6. If the information from the 1-year visit had been used in a caries risk model at the 1-year visit and interventions had been made, the caries situation at the follow-up might have been different. Environmental and family factors are important to include in a risk model at an early age. This is in line with Antunes and Featherstone (57, 91). As Featherstone wrote: "A combination of all factors that affect caries development should be included in caries risk assessment" (57).
A common risk program for all age groups in a clinic tends to work worse than risk programs tailored for the individual age group. Predictive ability differs with age group because certain factors are more important at some ages and less at others. Thus, caries risk is age specific. Supplementing a caries risk assessment tool with questions about environmental and social conditions, and thus, improving the predictive ability of the caries risk assessment in the youngest age group, in preschool children, would be desirable. The results from the Papers in this thesis show the importance of using data from the environment and the social circumstances in which the child lives, in order to improve and refine the caries risk assessment for young children. Collectively,

the works in this thesis offer suggestions for a new risk model. A caries risk model should be designed for preschool ages because environmental and social indicators have been shown to be more important for the preschool child. Young children cannot take responsibility or make decisions for themselves, but they are referred to the behavior of their caregivers regarding health habits. Younger children are more affected by their social situation than older children (61, 62, 123).

In this thesis risk factors and risk indicators in preschool children showed increased prediction when extended to the common caries risk assessment with unique individual data, thus, one recommendation is to collect data from environmental and social indicators in order to supplement the existing assessment model, R2 (Table 17).

Table 17. Recommendations for supplemental factors and indictors that would improve the predictive ability of the caries risk assessment tool, R2, for preschool children.

Factors and indicators	Items	Supplement to R2
General health	Systemic disease	
	Medication	
Oral factors	Caries experience[a]	
	Plaque on teeth	
Dietary factors	Night meal[b]	✓
	Snacking[c]	
	Drinking other than water between meals	✓
Oral hygiene	Tooth brushing[d]	
Protective factors	Fluoride use	
Environmental indicators	Siblings with caries[e]	✓
	Number of siblings[e]	✓
	Family situation[f]	✓
Social indicators	Education level of parents[g]	✓
	Foreign background[h]	✓

[a] Signs of clinical caries (4)
[b] night meals after age 1 year
[c] > 3 snacks/day
[d] tooth brushing once or twice a day with or without support
[e] siblings with caries, having ≥ 3 siblings
[f] living in a single-parent family
[g] low parental educational level (≤ 9 years)
[h] child or parents born in foreign country (non-Nordic)

The predictive ability of caries risk assessment increased when it was done closer to the follow-up. This confirms that caries risk assessment should be revised frequently and regularly. A caries risk assessment provides a snapshot of the child's caries risk factors, risk indicators, and protective factors for that very moment. Caries risk factors and risk indicators may change over time, and updating and expanding information about the child is necessary. Thus, caries risk assessment needs to be revised over time. This is in line with Twetman (99, 133). Major events in the family such as separation, new siblings, and a new family member can affect the child's sense of security in their situation and risk factors and risk indictors for caries. Therefore, regular frequent contact with the family in order to update information about the family situation is important. The frequency of such contacts could be based on the previous

caries risk assessment and done either in-person or digitally, considering today's technique. Of course, determining the general oral status should be done in-person. This is especially important when it comes to children and the responsibility that dental care has in the social safety net.

An in-person meeting with the young child and their guardian is necessary for assessing diet and oral hygiene habits. Caries risk assessment is based mainly on oral factors. Thus, frequent in-person visits are essential, also because caries risk assessments have limited durability.

Children with a high risk of caries development could need both in-person and digital support. When caries risk is low and in-person visit intervals are long, digital care meetings could occasionally suffice, but in the long term, they could never replace the in-person visit with a clinician. Digital visits are mainly opportunities for updating contact information and changes in environmental and social indicators. When changes that could affect caries development do occur, in-person support from the dental health care team could be important. Another purpose of the clinical visit is to look at the child's overall situation, to discover children who are exposed to neglect or child abuse, in addition to caries and dental development that can affect their quality of life (134). There is a risk that the limited public resources for dental care might cause recall intervals to be revised, with some being replaced with digital meetings (132, 135). Even if recall intervals are extended publicly, it is important not to lose contact with the family; this applies especially to families with young children.

In Sweden, the National Board of Health and Welfare recommends that children with an assessed, low risk of oral disease should have dental visits at 18–24-month intervals, and children with a high risk of oral disease, at 12–15-month intervals (132). Oral health in children's dentistry includes more than caries, tooth development, tooth structure, bite deviations and follow-up after dental trauma. The recommendation to extend the interval between examinations for children with a low risk of oral health may mean that a change in the risk of caries, depending on changed circumstances in the family, the intervals become too long from a caries perspective. This is a consideration when extending intervals up to 24 months for a young child.

Dahlgren & Whitehead described the social determinants in the family that influence parental behaviors and capability to implement suggested changes in oral habits (39). Parental habits, behavior, and priorities are guided by held attitudes and based on level of knowledge and health literacy that is, the ability of individuals to acquire, understand, and use information to maintain,

promote, or improve health (123, 136). Currently known social factors associated with caries are not easy to change; thus, it is important that we learn about these factors in order to create supporting functions for families and their children.

METHODOLOGICAL ASPECTS

The PDS clinic in Papers I–III served several residential and socioeconomic areas. Caries experience in this catchment area can be described as low compared to figures for the region and national figures. Since data collection occurred over the span of 2004–2015 in Papers II and III, a change over time was observed for caries experience (deft > 0; Table 1).

Caries status in the catchment area of Papers II and III was below regional and national levels. Thus, their results may not be generalized nationally. They have relevance for an area with a low prevalence of caries. These results may also be affected by the inclusion in Paper I, which consisted of those who came to the first visit at age 1 year; no further analyses were done for those who dropped out.

The study cohort in Paper IV comprised all children born in 2012 in Kalmar County. Caries experience for children aged 3 years was shown to be 6% and at the documented national experience at that time, was 5%. For children aged 6 years, caries experience was shown to be 25% and at the national level, 24% (Table 1). Thus, caries experience in Paper IV is comparable for both regional and national levels. The results Paper IV can be considered generalizable.

The differences in caries experience in a population affect the predictive ability of risk models. In Papers III and IV, caries experience in 6-year-old children varied between 16% and 25%, which could increase the predictability of caries risk models.

Children who were judged to be at risk of developing caries in Papers I–IV received preventive treatment in the form of information, fluoride, and non-invasive and invasive treatment to prevent caries development or progression. Not offering treatment as standard procedure would have been unethical. Despite the planning of preventive efforts, there were children who did not come to the visits, which then meant that changes in possible risk factors could not be influenced.

Comparing the results and variables in the papers with other studies is problematic. Generally, fewer variables are studied, and the variables are named and categorized differently in the predictive risk models. Havsed found that different studies considered 150 predictors similar, and that between 3 and 46 variables had been included in various risk models (120).

ETHICAL CONSIDERATIONS

Ethical approval:

Papers I–III: The Regional Ethics Board at Linköping University, Linköping, Sweden (Daybook no. [Dnr] M126-06, 2011/465-31, and 2018/344-32).

Paper IV: Swedish Ethical Review Authority (Daybook no. [Dnr] 2021-00887, supplements 2022-01739-02 and 2022-03206-02.

The Regional Ethics Board and PDS in Östergötland approved data collection from dental records. “Evaluation of methods for caries risk assessment in preschool age” (Papers I-III).

In 2020, Sweden adopted The United Nations Convention on the Rights of the Child (UNCRC) as law (137). It defines children’s rights to be healthy, grow, develop, and have a good quality of life (137). Since 2015, the United Nations has adopted 17 global goals. Number 3 is “ Good Health and Well-being. Ensure healthy lives and promote well-being for all at all ages” (138).

Caries, a non-communicable disease, is still a common disease in children that affects their quality of life. Experience of caries causes pain and infection and affects daily life. The experience also affects eating and disturbs sleeping, which could influence physical growth. It is important to develop caries risk models in order to find individuals at risk of developing caries, even in regions with a low caries prevalence, to avoid caries development. By refining the caries risk assessment and preventing the development of caries, the quality of life can be improved for both the child and the guardian. Risk factors and risk indicators affect children differently at different ages. Several studies have pointed out that risk models should be designed and calibrated in the region they will be used in (97).

The continual refining of caries risk assessment is important, as we know caries not only affects the quality of life in the short term, but also raises the risk of future problems in adulthood. The etiology of caries is known, so directed prevention of caries will improve the quality of life. The purpose of tailored

prevention strategies, results of highly reliable caries risk assessments, are to optimize the planning of interventions. Reduced caries prevalence leads to a better quality of life for both the child and the family. Societal financial costs are also reduced if fewer reparative treatments are needed (139). Resources in dental care are limited and those who are most in need and at highest risk must be prioritized for care. Children should be neither over-treated nor under-treated.

Papers I–IV incurred neither benefit nor harm in the study cohorts. A hope is that children of tomorrow can benefit from the research findings through a caries risk assessment with higher quality and accuracy. Improving the quality and accuracy of risk assessments allows healthy children with a low risk of disease to be more easily detected, so that public funds for unnecessary clinical examinations can be used elsewhere more urgent (95). This research highlights various risk factors and risk indicators for preschool children. To have a greater impact on caries preventive efforts, dental care needs to collaborate with other health and social actors. The research shows that caries risk factors and risk indicators exist to different extents and with different compositions and groupings and must then also be handled in different ways.

Objective caries risk assessment analyses, especially in preschool children, are essential as caries and its following consequences and treatment are hard to uncomprehend in young ages. In addition, this group has little opportunity to make their voice heard about importance of optimized caries risk assessment due to their age and level of maturity and are therefore especially vulnerable. For this age group it is important to have an aged-specified caries risk assessment model. The caries risk assessment in young children is a help to prioritize the children with the greatest need for dental care. With limited resources, the dental care carried out is forced to be prioritized, and in addition, the resources must be used cost-effectively.

In Paper I, the bacterial test was part of the routine visit at age 1. All data were retrieved from dental journal records. The children underwent no additional treatment (Papers I–III).

In Papers I–III, the security numbers on the files were removed and data were anonymized before statistical analyses began.

In Paper IV, data from two registries (SKaPa and SCB) were used. The data contained information on the patient's relatives, which is considered sensitive;

this was taken into account and protected. Data were sent encrypted with double authentication between researchers, SKaPa, SCB, and back to researchers. SCB merged all data, replacing the Swedish personal identity numbers with serial numbers. Thereafter, it was impossible to trace any individual throughout the studies.

STRENGTHS AND LIMITATIONS

A limitation of Paper I was that the dropouts were not documented. It would have been interesting to compare the caries experience of those children to the included children in Papers II and III. As a strength, four dental professionals participated in the work of the 1-year visits during 2001–2010. At the child's 1-year visit the bacterial sampling and caries risk assessment were done by the same person. In Papers II–IV, several therapists participated over the years, which could be a disadvantage since stances on diagnosis and caries risk assessment can vary between individuals, however, this is how reality looks and can be considered realistic. Working with well-known county routines and guidelines enables equivalent assessments as far as possible.

Experience of dentin caries was retrieved from the dental records of the clinical examination and not of enamel lesions. This may be a limitation because enamel lesions are a first sign of caries disease. In Papers I–III, all data were collected from one PDS clinic, which, however, involved different socio-economic and demographic areas. This can be a disadvantage as it reflects a specific catchment area. In contrast, data were collected throughout one county in Paper IV which included different socioeconomic and demographic areas. A larger catchment area may be an advantage. However, there was no metropolitan area in the county, which might be a limitation.

In Paper III, oral factors like gingival conditions, oral hygiene, and dietary habits are not presented separately, since they were included in risk assessment. In Paper IV, gingival conditions, oral hygiene, and dietary habits could not be retrieved from the registries. An advantage would have been to present the data in the caries risk assessment separately. The caries risk assessment in Papers III and IV provides an overall assessment and not information about specific risk factors, for example, diet or hygiene habits. This is a limitation. Oral and dietary habits have a great impact on the predictive ability of caries risk assessments in preschool children (131).

CLINICAL ASPECTS

The knowledge that caries prevalence (deft > 0) at age 6 is increasing may be a sign that the caries risk programs are not adapted to children and changing societal circumstances. The used programs fail to detect some of the children who are at risk of developing caries. One reason is that the caries risk programs are not adapted for different ages, thus new programs tailored for different age groups would be a great clinical benefit.

Caries risk assessment plays an important role in planning return visit intervals, which today are based on the risk to the child's oral health. Children with a low risk of developing caries may have a recall interval as long as 24 months.

In the perspective of the child, 24 months is a long time, especially if we rely on a caries risk assessment that lacks factors which may affect oral health development or if the child's environment changes. In the short perspective, there could be consequences for caries development in the primary dentition. Even if the caries risk of the child is low, regular contact with dental care at individualized intervals is important. The dental team has an important role when meeting the children and the guardians, to note changes that may be affecting the child's overall well-being.

The R2 caries risk assessment relies on an algorithm-based program to and deliver a proposal. A caries risk assessment done manually uses a combination of assessment forms and clinician knowledge acquired through previous experience of assessments. The gut feeling about caries risk that Mejare, among others, previously touched upon is difficult to explain but is dependent on professional experience, which is under development in those who have worked for a shorter time in dental care. Public dental care and other actors who meet children and families regularly are important for finding children who are in the risk zone, for impaired health and quality of life, and then providing family support measures. Here, a collaboration could be an advantage. The Swedish National Board of Health and Welfare has recommended special interventions for families living in vulnerable socioeconomic areas (132).

Since the causes of caries disease are multifactorial and well-known, there is strong evidence that caries risk assessments should include more than oral elements (57). Nevertheless, it is common for risk programs to omit information on social and environmental indicators, relevant to the risk of developing caries disease for preschool children. This can be compared to the

scenario where a doctor has a patient with breathing problems and fails to ask about smoking, leaving out factors that are well known to affect breathing.

Caries risk programs should be general, that is, able to be used by dental personnel who can and must diagnose caries. The programs should be easy to learn, and users should be able to evaluate and validate their patient's caries risk better. It is also clear that different ages have specific risk factors and risk indicators that affect caries disease. How to validate risk programs designed for different age groups? Adopting a caries risk program that has been evaluated in areas where caries prevalence, living situations, and culture differ will fail to address the new situation, therefore validation should be done in the region it will be used in.

Health economy

Health economic evaluation of the health benefits of caries risk assessment in children are complicated to analyze. To counteract the development of caries, the first step is to perform a caries risk assessment and thereafter interventions are planned and performed.

The interventions that are planned and carried out vary both at the clinic and at home. Because caries is a multifactorial disease, it is difficult to evaluate which different interventions give the best results. This means that it becomes complicated to make a cost analysis of the health benefits of the caries risk assessment. Even though it is complicated, it is important that an analysis of the health effects of the risk assessment is made. In order to evaluate implemented measures after a performed caries risk assessment, randomized studies can be carried out, but this entails ethical problems because different treatments on children with a high risk of caries will then be carried out.

6 CONCLUSION

This is the conclusion of the general aim:

> An overall caries risk assessment should include environmental and social factors and information from an oral examination. Anamnestic questions at one year of age can replace salivary test to find the risk factor mutans streptococci. Social factors have a higher impact on the dental health of young children than on older children.

These are the conclusions of the Papers:

> Paper I: Early colonization of mutans streptococci in 1-year-old children is associated with *siblings with caries*, *drinking other than water between meals.*
>
> Paper II: Children with caries at age 3 years had *presence of a high level of mutans streptococci*, *siblings with caries, beverages other than water between meals,* and *night meals,* at one year of age.
>
> Paper III: Children with caries at 6 years of age had *presence of mutans streptococci, siblings with caries, night meals, beverages other than water between meals,* at one year of age. Caries risk assessment at age one has low sensitivity and high specificity to predict caries at age 6 years in a region with low caries prevalence.
>
> Paper IV: A caries risk assessment based solely on oral factors at age 3 has limited ability to predict caries at age 6 years. Predictive ability in younger children increases when social indicators are combined with a caries risk assessment. In addition, caries risk assessments have limited durability.

7 FUTURE PERSPECTIVES

Caries risk assessment is important in dental care for promoting dental health and individualizing care. The risk assessment must also function as an educational tool to visualize the assessment with risk factors and health factors for the patient. The caries risk assessment that is carried out today in pediatric dental care is mainly good but could be even better. The risk programs used today in PDS clinics are primarily focused on the entire patient register from 0 to 100 years of age, with certain exceptions. Risk factors have different effects at different ages, so caries risk programs need to be designed for specific ages.

Because caries is a multifactorial disease, factors outside the oral cavity, like risk indicators, also need to be implemented in the caries risk programs. As the child grows, the impact of individual variables will change. Caries risk programs across Sweden vary. The variables in the caries risk programs will also be weighted differently. This would be interesting to investigate and analyze for which ages the programs are best suited. This thesis developed a proposal for an extended version of the caries risk assessment tool, R2, which would benefit from being tested for wider use.

It is also of interest to analyze what treatment the preschool children received after the caries risk assessment, whether it was over-treatment or under-treatment, and to see if this treatment changes the risk of caries, and how the return visits are planned.

In Sweden, the counties are responsible for planning children's dental care, which can be carried out in both public and private dental care. Swedish counties are governed by politicians, who select which patient groups are to be prioritized. Children with acute problems, but also children in general, are one prioritized group. Resources are not infinite, but they must be planned so that those who need the most support will receive it, without avoiding the needs of healthier groups.

When parents bring their children to dental care, they meet different staff member and are naturally treated in different ways. Public dental care in Sweden has various structures for the care of children and their families. Something that would be interesting to study is parental perception of the information provided in dental care when their children visit. The information itself, but also how it is presented, is probably important for how it is received by parents. This could be evaluated in a qualitative study from semi-structured

interviewing of parents to preschool children, with varying caries experience, who have visited PDS clinics.

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