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ORIGINAL ARTICLE

Association of dietary calcium, phosphorus, and magnesium intake with caries status among schoolchildren

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Abstract The aim of this study was to investigate the associations between caries experience and daily intake of calcium (Ca), phosphorus (P), magnesium (Mg), and Ca/P ratio. A total of 2248 schoolchildren were recruited based on a population-based survey. Each participant received a dental examination and questionnaire interviews about the 24-hour dietary recalls and food frequency. The daily intake of Ca, P, Mg, and Ca/P ratio were inversely associated with primary caries index, but only the Ca/P ratio remained significant after adjusting for potential confounders. According to the Taiwanese Dietary Reference Intakes, the Ca/P ratio was related to both caries in primary teeth (odds ratio = 0.52, $p = 0.02$) and in permanent teeth (odds ratio = 0.59, $p = 0.02$). The daily intakes of Ca/P ratio remained an important factor for caries after considering potential confounding factors.

Conflicts of interest: All authors declare no conflicts of interest.

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Introduction

Nutritional factors are generally associated with several systemic diseases, gastrointestinal disorders, most cancers, as well as oral diseases [1]. The most common chronic oral disease, dental caries, may lead to pain from untreated teeth, reduced chewing ability, nutritional insufficiencies, lower self-esteem, and the problems of speaking and learning in schoolchildren [2].

Dental cavities are caused by the demineralization of tooth enamel by acids, such as lactate and acetate, formed from the fermentation of sugars and starches by dental plaque bacteria. *In vitro* studies show that milk or dairy products can reduce enamel solubility, promote its remineralization, and prevent the adhesion of mutans streptococci to the tooth surface [3]. In terms of the relationship between dietary minerals intake and oral disease, the calcium (Ca) and phosphorus (P) concentrations of dental plaque and the levels of Ca and P ions in the saliva could affect the balance between demineralization and remineralization of enamel [4]. Some epidemiological studies have revealed that humans with relatively high Ca and P in their plaque experience correspondingly lower caries [5]. In addition, Stanton [6] found that the dietary Ca/P ratio was strongly associated with caries development in human teeth, and indicated the effect of anticariogenicity when the dietary Ca/P ratio was 1.1 or 1.2. Stanton [6] also inferred that the dietary Ca/P ratio could influence the enzymic activity in oral bacteria. However, recent studies have disagreed and shown a less important role of the Ca/P ratio in caries development. Some epidemiological investigations have revealed there is no significant relationship between caries and dietary Ca/P ratio [7]. Similarly, magnesium (Mg) has also been shown to have both significant [8] and nonsignificant [9] associations with tooth decay.

The major food sources of minerals have been reported by Wu et al. [10] for Taiwanese schoolchildren. The dietary intake of Ca was 31.5% from dairy products (fresh milk, yogurt, cheese, and other dairy products) and 10.3% from dark-green/yellow vegetables. For the intake of P, dairy products and pork/pork products contributed about 14.9% and 12.0%, respectively. Mg intake was mainly from rice/rice products (10.5%).

An earlier study in Taiwan showed that daily milk consumption was significantly associated with a lower risk of permanent teeth decay in schoolchildren [11]. However, Yen et al. [12] indicated that neither dietary intake of Ca and P nor dietary Ca/P ratio was significantly associated with dental caries in preschool children. Therefore, the purpose of this research was to investigate the associations among caries experience and intakes of Ca, P, Mg, and Ca/P ratio in a population based cross-sectional study of elementary schoolchildren.

Methods

Study participants and study design

This study used the database of the Nutrition and Health Survey in Taiwan Elementary School Children 2001—2002 (NAHSIT Children 2001—2002), which is a population-based survey investigating the nutrition and health status of elementary schoolchildren in Taiwan. Towns and districts were classified into 13 strata by particular ethnic and geographical characteristics, which included Hakka areas, mountain areas, eastern Taiwan, the Penghu Islands, three northern regions, three central regions, and three southern regions. One hundred and four schools were selected (8 schools from each stratum), and within each school, 24 students were randomly selected (4 students from each grade) based on the "probabilities proportional to sizes" approach. The survey included face-to-face interviews and physical examinations (including dental examination). A total of 2248 schoolchildren (1196 boys and 1052 girls) aged 6—12 years participated in this survey and completed both interviews and dental examination. Informed consent was signed by one of the parents of each participating child. This study was approved by the Institutional Review Board (Human Experiment and Ethics Committee, Kaohsiung Medical University Hospital, MUH-IRB-990027). More detailed description of the sampling design is provided in Tu et al.'s report [13].

Dental examination

Each participant received a dental examination and a personal interview. We followed the guidelines of the *Oral Health Surveys—Basic Methods* (4th edition) for dental examinations with dental mirrors and CPI (Community Periodental Index) probes. Three dentists participated in the survey. The presurvey calibration practice yielded 0.79, 0.80, and 0.90 for the kappa coefficients on caries diagnosis. During the survey, 5% of the students were reexamined by a second dentist, and the kappa coefficients were 0.77, 0.80, and 0.82. Student caries status was recorded as the DMFT index [D (decayed), M (missing due to caries), F (filled)] of the permanent teeth and the deft index [d (decayed), e (indicated for extraction), f (filled)] of the primary teeth. The DMFT and deft indexes were further categorized into three groups, in which Group 1 was for caries index being 0, Group 2 was for caries index being 1—3, and Group 3 was for caries index being 4 or higher.

Questionnaire

Questionnaire information, which included sociodemographics, tooth brushing habits, fluoride exposure, 24-hour dietary recalls, and food frequency, was collected by trained interviewers. Body mass index (BMI) was also obtained from the physical examination. Dietary mineral (Ca, P, and Mg) intake was assessed using data from 24-hour dietary recalls during household questionnaire interview. Interviewers used several tools, including food piece models, abstract food models, measuring cups, spoons, and electronic weight, to help the participants recall the amount of foods individuals consumed. The collected information of food models were first transformed into weights of foods consumed, and then the amounts were calculated using the Assessment of Chinese Dietary Intake system, developed by the Institute of Biomedical Sciences and the Institute of Information Science, Academia Sinica [14]. The major nutrient databases included "Nutrient composition Data Bank for Foods in Taiwan Area" and "Composition Data Bank for Foods in