European Journal of Clinical Nutrition (2008) 62, 18–31

0954-3007/08 $30.00
www.nature.com/ejcn

ORIGINAL ARTICLE

Twelve-year follow-up study of the impact of nutritional status at the onset of elementary school on later educational situation of Chilean school-age children

D Ivanovic[1], M del P Rodríguez[1], H Pérez[1], J Alvear[1], N Díaz[1], B Leyton[1], A Almagià[2], T Toro[2], MS Urrutia[3] and R Ivanovic[1]

[1]*Nutrition and Educational Achievement Unit, Institute of Nutrition and Food Technology (INTA), University of Chile, Santiago, Chile;* [2]*Institute of Biology, Laboratory of Physical Anthropology and Human Anatomy, Catholic University of Valparaíso, Valparaíso, Chile and* [3]*PAHO/WHO, Washington, DC, USA*

Objective: To determine the impact of nutritional status in a multicausal approach of socio-economic, socio-cultural, family, intellectual, educational and demographic variables at the onset of elementary school in 1987 on the educational situation of these children in 1998, when they should have graduated from high school.
Setting: Chile's Metropolitan Region.
Design: Prospective, observational and 12-year follow-up study.
Methods: A representative sample of 813 elementary first grade school-age children was randomly chosen in 1987. The sample was assessed in two cross-sectional studies. The first cross-sectional study was carried out in at the onset of elementary school in 1987 and the second was carried out in 1998, 12-years later, when they should be graduating from high school. In 1998, 632 adolescent students were located and their educational situation was registered (dropout, delayed, graduated and not located). At the onset of elementary school were determined the nutritional status, socio-economic status (SES), family characteristics, intellectual ability (IA), scholastic achievement (SA) and demographic variables. Statistical analysis included variance tests and Scheffe's test was used for comparison of means. Pearson correlation coefficients and logistic regression were used to establish the most important independent variables at the onset of elementary school in 1987 that affect the educational situation 1998. Data were analysed using the statistical analysis system (SAS).
Results: Logistic regression revealed that SES, IA, SA and head circumference-for-age *Z* score at the onset of elementary school in 1987 were the independent variables with the greatest explanatory power in the educational situation of school-age children in 1998.
Conclusions: These parameters at an early school age are good predictors of the educational situation later and these results can be useful for nutrition and educational planning in early childhood.
Sponsorship: This study was supported in part by Grants 1841167 and 1880818 from the National Fund for Scientific and Technologic Development (FONDECYT), Grants S 2169-924F and EO11-97/2 from the University of Chile, Research Department (DI), and by Grant 019/1997 from the University of Chile, Postgradest Department.
European Journal of Clinical Nutrition (2008) **62,** 18–31; doi:10.1038/sj.ejcn.1602672; published online 21 February 2007

Keywords: child nutrition; nutritional assessment; student dropout; intelligence; education; socio-economic factors

Correspondence: Professor DM Ivanovic, Institute of Nutrition and Food Technology (INTA), University of Chile, Avda. El Líbano 5540, Santiago, Chile.
E-mails: inta8@abello.dic.uchile.cl; daniza@inta.cl; www.inta.cl
Guarantors: DM Ivanovic and RM Ivanovic.
Contributors: MdPR is responsible for the field study and conscript data; HP contributed to write and refined the manuscript; ND and BL for statistical analysis; JA, AA and TT advised on the study design and interpreted the current findings; MSU for the intellectual assessment.
Received 12 April 2006; revised 2 January 2007; accepted 4 January 2007; published online 21 February 2007

Introduction

School desertion is one of the most relevant educational problems in the world. However, in Chile, research aimed at acquiring knowledge about its causes and consequences is scant.

The impact of being over age for grade during adolescence may explain a large proportion of the higher dropout and school failure rates among retained youngsters (Roderick, 1994). Other results demonstrated that independent of socio-economic stratum, children older for grade have a significantly lower intellectual quotient and scholastic achievement (SA), decreased brain parameters, a deprived nutritional status and a higher course repetition rate (Ivanovic *et al*., 2002).

Nutritional status is a variable of considerable importance during school age as it affects both intelligence and SA (Ivanovic *et al*., 1996, 2000a, b, c, 2002, 2004c). Head circumference, an indicator of nutritional background and brain development, is the most important anthropometric parameter associated with intelligence and SA; even more, school dropout relates with HC but not with weight or height (Ivanovic *et al*., 1996).

School performance is associated with health, nutritional, anthropological and behavioural determinants. The consequences of the overnight and morning fast, particularly among children nutritionally at risk, included slower stimulus discrimination, increased numbers of errors and slower memory recall. These alterations may result from a state of metabolic stress in which homeostatic mechanisms attempt to maintain circulating glucose concentrations (Pollitt *et al*., 1998). Other findings suggest that omitting breakfast interferes with cognition and learning, an effect that is more pronounced in nutritionally at-risk children than in well-nourished children; at the very least, breakfast consumption improves school attendance and enhances the quality of the students' diets (Pollitt and Mathews, 1998).

Depreciation of learning has been described as the primary motive for dropout. Responses to questions about dropout motivations indicate that the dropout population does not adhere to the normative values system and is ill-adapted to the educational system in general (Kaplan *et al*., 1995; Hrimech and Theoret, 1997). In female adolescents, pregnancy is an important cause of desertion and some authors suggest that dropping out of school among pregnant adolescents may be more strongly related to socio-cultural factors than to individual characteristics such as emotional support and psychological well being (Stevenson *et al*., 1998).

Tracking of the educational progress of Baltimore children from their first grade, during 1982–1996 revealed that family context measurements (stressful family changes, parents' attitudes and parents' socialization practices), children's personal resources (attitudes and behaviour) and school experiences (test scores, mark and track placements) influenced dropout independently of socio-demographic factors; these variables account for much of the difference in the probability of dropout associated with family socio-economic status (SES), gender, family type and other risk factors (Alexander *et al*., 1997). The effects of change in family structure and income on dropping out of middle and high school have been well documented (Pong and Ju, 2000).

The mental health implications of not graduating from high school have been analysed in the seventh grade and again when subjects were young adults. Results suggest a significant negative effect of not graduating on later psychological functioning that could not be accounted for solely by deprivation of a college education, because the same effect was observed when considering only school-age children who did not go on to college (Kaplan *et al*., 1994).

The educational situation of school-age children (dropout, delayed or graduated) is a multicausal problem whose variables depend on the child, his/her family and the educational system. Other findings point out that independent of socio-economic stratum, sex and age, maternal intellectual quotient or maternal schooling, brain volume and undernutrition in the first year of life are the main determinants of intellectual quotient and this in turn is the most relevant parameter that explains SA (Ivanovic *et al*., 2000a, b, 2002).

The objective of this study was to determine the impact of nutritional status in a multicausal approach of socio-economic, socio-cultural, family, intellectual, educational and demographic variables at the onset of elementary school in 1987, in children from Chile's Metropolitan Region whose educational situation was evaluated 12 years later, when they should be graduating from high school. The final purpose was to contribute to the establishment of a model of the behaviour of the independent variables affecting school desertion.

Materials and methods

Study population and sample

This is a prospective, observational study of a 12-year follow-up of the impact of nutritional, socio-economic, socio-cultural, family, intellectual, educational and demographic variables at the onset of elementary school in 1987 on the educational situation evaluated 12 years later, in 1998, when adolescent school-age children should be graduating from high school. The target population, 75,138 children, included all school-age children who were enrolled in first grade of elementary school in the Metropolitan Region of Chile in 1987 (mean age was 6.5 ± 0.4 years; range 5.5–9 years). The sampling system was designed to yield a sample including approximately 1.0% of this population. The representative and proportional sample consisted of 813 school-age children randomly selected and stratified according to a multistage sampling system by geographic area, sex and type of school (Figure 1). Sample size in each stratum was proportional to the size of the stratum in the school-age population and was calculated with 95.0% reliability and with a precision of 5%. The 813 elementary first grade school-age children were assessed in two cross-sectional studies. The first cross-sectional study was carried out in 1987 and it determined their nutritional status, socio-economic stratum, socio-cultural, family and demographic characteristics, intellectual ability (IA) and SA. This initial survey was carried out in 13 schools that belonged to eight of

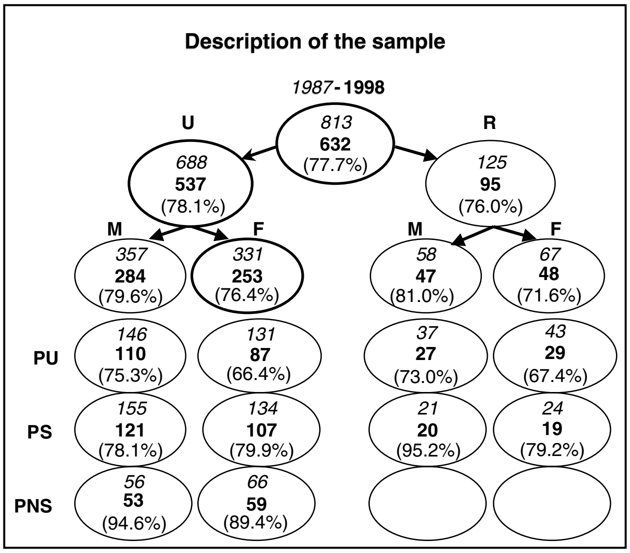

Figure 1 Description of the sample studied in 1987 (italics) and in 1998 (boldface); the percentage of 1987 elementary students contacted in 1998 is shown between parentheses. U, urban; R, rural; M, males; F, females; PU, public schools; PS, private subsidized schools; PNS, private non-subsidized schools. In the rural areas there were no PNS.

the counties of the Chile's Metropolitan Region; this sample is representative of 38.0% of the Chilean school-age population (Chile. Ministerio de Educación Pública, 1987). The second cross-sectional study was carried out in 1998, when they should be graduating from high school (mean age 18.0$\pm$0.7). After 12 years, 632 school-age children (77.7% of the initial sample) were located in their original educational establishments, in their homes or in Chilean universities (Figure 1). The high percentage of students located after 12 years assures sample reliability. The procedures put in place to locate students were to send a letter to student's home, phone calls, consultation to public records such as phone books and Chilean university registrations. Their educational situation in 1998 was classified as graduated, delayed, dropout (children who leaved school without returning to it) and not located. This study was approved by the Committee on Ethics in Studies in Humans of the Institute of Nutrition and Food Technology (INTA), University of Chile. The subjects' consent was obtained in both periods according to the norms for Human Experimentation, Code of Ethics of the World Medical Association, Declaration of Helsinki (The World Medical Association, 1964).

Measures

Anthropometric measurements 1987. Weight (W), height (H), head circumference (HC), arm circumference (AC) and triceps skinfold (TS) were measured by the authors applying standardized procedures (Gibson, 1990). Nutritional status was expressed as weight-for-age *Z* score (Z-W) and height-for-age *Z* score (Z-H) and weight-for-height *Z* score (Z-WH) (National Center for Health Statistics, 2000). On the basis of Z-W and Z-WH, children were distributed into four categories: undernourished (*Z* score <-1 s.d.), well nourished (*Z* score between -1 and $+1$ s.d.), overweight (*Z* score between $+1$ and $+2$ s.d.) and obese (*Z* score $>+2$ s.d.); when Z-H was considered, children were classified as growth failure (*Z* score <-1 s.d.), normal height (*Z* score between -1 and $+1$ s.d.) and tall (*Z* score $>+1$ s.d.). Their body mass index (BMI, evaluated as W/H^2) was compared with NCHS-CDC tables (National Center for Health Statistics, 2000). Raw head circumference (HC) was compared with the tables of Nellhaus (1968); Tanner (1984); Roche *et al*. (1987); Ivanovic *et al*. (1995a) and was expressed as *Z* score (Z-HC). Z-HC values were similar when applying these tables because the correlation coefficient between these patterns was 0.98 (Ivanovic *et al*., 1995a). In this respect, mean$\pm$2 s.d. was considered 'normal HC', <-2 s.d. microcephaly and $>+2$ s.d. macrocephaly (Nellhaus, 1968; Tanner, 1984; Roche *et al*., 1987), although it was classified as follows: <-2 s.d., $<$mean to -2 s.d., mean to $+2$ s.d. and $>+2$ s.d. HC was also adjusted by sex and body size (weight and height) through ANCOVA (Guilford and Fruchter, 1984). Percentages of adequacy to the median of arm circumference-for-age (% AC/A), triceps skinfold-for-age (% TS/A), arm muscle area-for-age (% AMA/A) and arm fat area-for-age (% AFA/A) were calculated using data from Frisancho (1981). Birth weight was used as an index of prenatal nutrition, Z-W, Z-H and Z-HC as indicators of postnatal nutrition and Z-WH and BMI were used as an index of current nutritional status. Nutritional diseases, especially undernutrition at an early age, were registered.

Dietary intake 1987. Standard procedures for 24-h dietary recall during individual interviews of mothers and children were used to collect data. Mothers and children were interviewed separately to determine child's food intake. A Chemical Composition Table for Chilean foods was used to calculate nutrient content of foods (Schmidt-Hebbel *et al*., 1990). The FAO/OMS/UNU (1985) pattern was used as reference for energy and protein intakes and dietary reference intakes (DRIs), for vitamins and minerals (FAO/OMS/UNU, 1985; Food and Nutrition Board, 2000a, b, c, 2002).

Socio-economic stratum (SES), socio-cultural and family-related variables, 1987. SES was measured applying a scale based on Graffar's modified method that includes schooling, occupation of the household head and characteristics of housing (building materials, ownership, water supply and ownership of durable goods), which had been adapted to Chilean urban and rural populations (Alvarez *et al*., 1985). This scale classifies a population sample into six SES: 1, High; 2, Medium-High; 3, Medium; 4, Medium-Low; 5, Low and 6, Extreme Poverty. Family variables such as the number of family members, number of siblings, place among siblings, crowding, family alcoholism and family recreation were registered. The quantity of exposure to mass media (MM) 1987 was assessed by means of a standardized questionnaire based on open and closed questions (Ivanovic and Sepúlveda, 1988). Mothers and children were interviewed separately to know SES, socio-cultural, family variables and the exposure to radio, cinema, TV, newspapers, magazines and books (other than school books) of the children.

Intellectual ability (IA) 1987. IA was assessed with the Raven's Progressive Matrices Test in book form, with a special scale for children 4–11 years that was standardized for Chilean school-age children (Raven, 1957; Ivanovic, *et al.*, 2000d, 2001). The test was administered individually by a team of educational psychologists and scores were recorded as a percentile scale according to age, in the following grading: Grade I, Superior Intellectual Ability (score ⩾p95); Grade II, Above Average (score ⩾p75 and <p95); Grade III, Average (score >p25 and <p75); Grade IV, Below Average (score >p5 and ⩽p25); and Grade V, Intellectually Defective (score ⩽p5). There was no difference between the percentile scales of the sample and those obtained by Raven. WHO experts for application in developing countries have recommended Raven's test because their results are not affected by cultural factors (Pollitt, 1983).

Scholastic achievement (SA) test 1987. SA was evaluated through standard Spanish language (LA) and mathematics (MA) tests especially designed for this study. The number of items explored was 16 and similar for LA and MA. Content validity was based on the fact that the test was prepared taking into consideration the objectives determined by the curricular programs of the Chilean Ministry of Education (Chile. Ministerio de Educación Pública, 1980). A pilot test was carried out in 55 school-age children, in which its reliability was determined applying the Spearman–Brown correlation, comparing paired and unpaired items scores being 0.92 and 0.97 for LA and MA, respectively (Guilford and Fruchter, 1984). Item-test consistency for each item was measured by Pearson correlation scoring values above 0.30 in all of them (Guilford and Fruchter, 1984). Results were expressed as percentage of achievement in overall results (SA) (LA + MA) as well as LA and MA independently. The number of school grades repeated was registered in 1998.

Statistical analysis

Data were processed using the Statistical Analysis System (SAS) package (SAS, 1983). Statistical analysis included variance tests (PROC ANOVA) to determine significant differences between the groups (not located, dropout, delayed and graduated) and Scheffe's test was used for comparison of means. Pearson correlation coefficients (PROC CORR) were calculated to decide if intercorrelated variables 1987 may be included as predictor variables of the educational situation 1998. χ^2 test and Fisher's test (PROC FREQ) were used to determine significant differences between the categorical variables. Logistic regression (PROC LOGISTIC) with the option Stepwise was used to establish the most important independent variables at the onset of elementary school in 1987 that affect the educational situation 1998, dependent variable, categorized as (i) dropout and non-dropout groups, (ii) dropout and delayed groups, and (iii) dropout and graduated on time groups; probability modelled was dropout = yes (Guilford and Fruchter, 1984).

Results

Table 1 resumes the nutritional background and the current nutritional status of the children at the onset of elementary school in 1987 as it relates to their educational situation in 1998. School-age children who graduated from high school in 1998 already had a nutritional background as well as brachial anthropometric parameters of body composition significantly better at the onset of elementary school in 1987 than their delayed or dropout peers. These presented in 1987 Z-W ($P<0.001$), Z-H ($P<0.001$) and raw Z-HC ($P<0.0001$) values significantly lower than those of delayed and graduated school-age children. It should be noted that Z-HC values differ in approximately one point when comparing dropout and graduated children. After adjustment for the effects of sex, body height and weight, adjusted values for HC did not differ significantly from absolute values from both males and females. As there were practically no significant differences between absolute and adjusted values for HC, only absolute values are shown in this study. School-age children not located had presented in 1987 nutritional parameters very similar to their delayed peers. Prenatal and the current nutritional status parameters in 1987 expressed as Z-WH and BMI were not significantly associated with the educational situation in 1998.

The nutritional status in 1987 expressed as categories of Z-W by educational situation in 1998 is shown in Figure 2. Undernutrition was already significantly more prevalent in 1987 in school-age children who dropped out from the educational system (23.2%) compared with delayed (14.7%) and graduated students (8.0%) ($P<0.01$). According to Z-H in 1987 (Figure 3), severe and moderate growth failure was significantly higher in 1987 at the onset of elementary school in dropout school-age children (11.6 and 36.2%, respectively) compared with their delayed (4.6 and 24.4%, respectively) and graduated peers (3.2 and 14.7%, respectively). However, the opposite was observed for height above the 90 percentile (taller) that was significantly higher in graduated (12.0%) than delayed (7.6%) and dropouts (4.4%) ($P<0.001$). Figure 4 shows that Z-HC 1987 values below the mean were significantly increased in dropout (75.4%) than in graduated school-age children (32.2%). From these results, 7.8% of graduated school-age children had Z-HC 1987 values >2 s.d. compared with their dropout (0%) and delayed peers

Table 1 Nutritional background, current nutritional status and brachial anthropometry of Chilean school-age children at the onset of elementary school in 1987 by educational situation 1998[a]

Nutritional status 1987	*Educational situation 1998*				F
	Not located (n = 181)	*Dropout (n = 73)*	*Delayed (n = 208)*	*Graduated (n = 351)*	
Prenatal nutritional background					
Birth weight (g)	3287.8±554.4	3182.0±412.2	3240.5±613.4	3322.4±582.7	0.93NS
Postnatal nutritional background					
Z-W	0.14 ab±1.03	−0.35c±0.88	0.06b±1.11	0.36a±1.02	10.12****
Z-H	−0.47 ab±0.96	−0.85b±0.95	−0.44a±0.97	−0.17c±0.97	11.34****
Z-HC	0.14a±1.11	−0.50c±0.97	0.15a±1.04	0.45b±1.25	14.43****
Current nutritional status					
BMI (W/H^2)	16.28±1.58	16.00±1.79	16.19±1.67	16.42±1.61	1.78NS
Z-WH	0.62±0.95	0.37±1.16	0.46±0.95	0.62±0.94	2.27NS
Brachial anthropometry					
% AC/A	99.2a±10.0	94.8b±7.0	98.9a±11.0	100.7a±10.2	6.61***
% TS/A	81.6a±28.5	77.3b±24.4	88.5a±40.6	87.0a±35.8	2.73*
% AMA/A	107.3a±24.7	97.2b±13.2	103.2ab±22.9	108.5a±21.3	6.44***
% AFA/A	82.1a±33.9	74.5b±26.5	88.6a±48.9	88.7a±41.9	3.08*

[a]Results are expressed as mean±s.d.
Abbreviations: *F*, variance; Z–W, weight-for-age *Z* score; Z–H, height-for-age *Z* score; Z–HC, head circumference-for-age *Z* score; BMI, body mass index; Z–WH, weight-for-height *Z* score; AC/A, arm circumference-for-age; TS/A, triceps skinfold-for-age; AMA/A, arm muscle area-for-age; AFA/A, arm fat area-for-age.
Means with the same letter are not significantly different at the 0.05 level based on Scheffe's test.
*$P<0.05$; ***$P<0.001$; ****$P<0.0001$; NS, not significantly different.

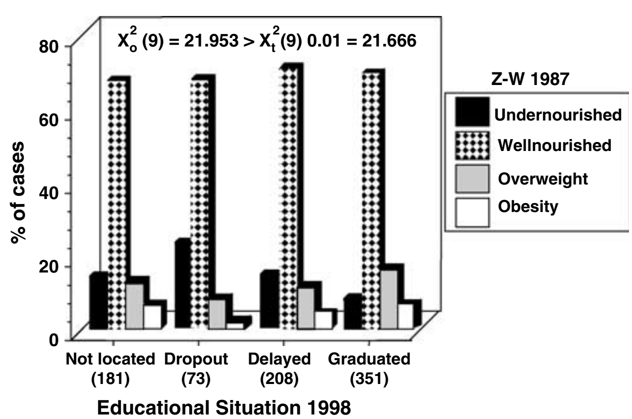

Figure 2 Nutritional status expressed as weight-for-age *Z* score of Chilean school-age children at the onset of elementary school in 1987 (Z-W 1987) by educational situation 1998. The number of cases in each group is indicated between parentheses. Undernourished, Z-W <−1 s.d.; well nourished, Z-W between −1 and +1 s.d.; overweight, Z-W between > +1 and +2 s.d.; obesity, Z-W > +2 s.d.

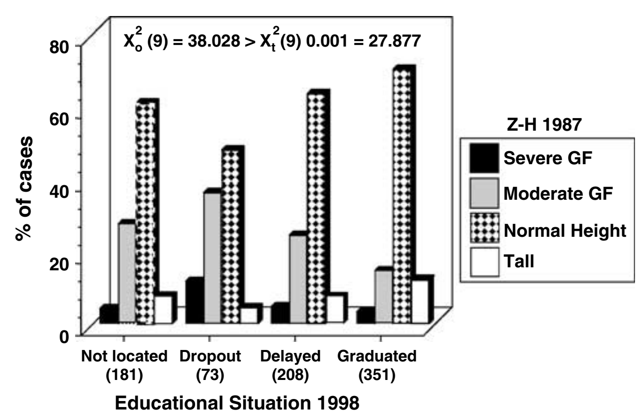

Figure 3 Nutritional status expressed as height-for-age *Z* score of Chilean school-age children at the onset of elementary school in 1987 (Z-H 1987) by educational situation 1998. The number of cases in each group is indicated between parentheses. GF, Growth failure; Severe GF, Z-H < −2 s.d.; moderate GF, Z-H between −1 and −2 s.d.; normal height, Z-H between −1 and +1 s.d.; tall, Z-H > +1 s.d.

(2.5%) ($P<0.001$). Comparable results were observed in the nutritional status 1987 expressed as Z-W, Z-H and Z-HC between not located and delayed groups (Figures 2, 3 and 4).

Table 2 shows the dietary intake of Chilean school age-children at the onset of elementary school in 1987 by educational situation 1998. Dropout school-age children registered in 1987 a lower dietary intake for most nutrients compared with their peers from the other groups; differences were significant for protein, calcium, zinc, riboflavin, niacin, pantothenic acid, saturated fatty acids and cholesterol; when dietary intake was expressed as percentage of adequacy, only protein intake did not show significant differences. As regard to energy sources, dropout students exhibited a percentage of calories from protein and a percentage of animal protein significantly lower than their peers from the other groups. Calories from fat were significantly lower in not located and

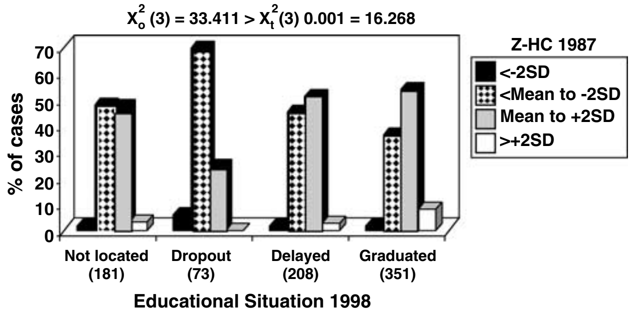

Figure 4 Nutritional status expressed as head circumference-for-age *Z* score of Chilean school-age children at the onset of elementary school in 1987 (Z-HC 1987) by educational situation 1998. The number of cases in each group is indicated between parentheses. χ^2 test was calculated comparing Z-HC values < mean and $\geqslant$mean.

dropout students but calories from carbohydrates were significantly higher in these compared with the rest of the sample. In general, nutrient intake of the not located school-age children was more similar to that of the delayed group.

The socio-economic and socio-cultural variables of Chilean school-age children at the onset of elementary school in 1987 analysed by educational situation in 1998 are summarized in Table 3. Most of school-age children that dropped out from the educational system belonged in 1987 to the low SES (87.6%), compared with their delayed (50.0%) and graduated peers (29.4%) ($P<0.001$). Occupation and schooling levels of both parents as well as housing conditions were significantly lower in dropouts than in delayed and graduated students ($P<0.001$). Mean paternal schooling was significantly lower in dropout school-age children (8.1a$\pm$3.6 years; $n=73$), than not located (10.8b$\pm$3.6 years; $n=181$), delayed (11.1b$\pm$3.3 years; $n=208$) and graduated groups (12.5c$\pm$3.3 years; $n=351$) ($F=34.50$; $P<0.0001$). Mean maternal schooling also was significantly lower in dropout (7.9a$\pm$3.0 years; $n=73$), than not located (9.9b$\pm$3.6 years; $n=181$), delayed (10.5b$\pm$3.2 years; $n=208$) and graduated students (11.8c$\pm$3.3 years; $n=351$) ($F=31.0$; $P<0.0001$). The opposite was observed for the number of family members who was significantly higher in dropouts (6.17$\pm$2.92; $n=73$) than in students who graduated (5.30$\pm$1.57; $n=351$) ($F=13.89$; $P<0.0001$) and a similar situation was observed for crowding defines as number of persons per bedroom) (1.05$\pm$0.57; $n=73$ and 0.83$\pm$0.41; $n=351$, respectively) ($F=25.06$; $P<0.0001$).

As regards to written MM, parents read them to children even through they had not learned to read yet in 1987. In this context, 74.8% of children did not read newspapers, 12.5% from time to time, 4.4% only on Sunday, 2.2% three times per week and 6.1% read it daily, without significant differences according to the educational situation 1998 ($X_o^2(9)=12.153$ < $X_t^2(9)0.05=16.919$). In 1987, 53.0% of school-age children read magazines without significant differences according to the educational situation 1998 ($X_o^2(3)=5.801$ < $X_t^2(3)0.05=7.815$). Book exposure was significantly different in relation to the educational situation 1998 as 27.3% of students who graduated from high school in 1998 read books at the onset of elementary school in 1987, a percentage that significantly decreased to 17.9 and 18.3% in delayed and dropout groups, respectively ($X_o^2(3)=9.973>X_t^2(3)$ $0.02=9.837$). In 1987, dropout school-age children listened to radio and watched TV an average of 38.8$\pm$65.3 and 140.3$\pm$69.2 min/day, respectively. Although these values are higher than the mean of the sample (30.7$\pm$43.7 and 128.5$\pm$81.6 min/day, respectively), differences between the groups were not significant. Not located and graduated school-age children went to cinema significantly more times per month (0.4a$\pm$1.0 and 0.4a$\pm$0.9, respectively) when compared with their dropout and delayed peers (0.2b$\pm$0.5 and 0.3b$\pm$0.8, respectively) ($F=3.02$ $P<0.05$).

Table 4 shows the intellectual, demographic and educational variables 1987 by educational situation 1998. IA Grade 1 was significantly more prevalent in graduated (9.9%) than delayed (0.5%) and dropout (0%) students. The opposite was observed for IA Grades IV and V, being significantly lower in graduated (15.9 and 6.7%, respectively) than delayed (22.6 and 11.3%, respectively) and dropout (34.3 and 24.3%, respectively) groups ($P<0.001$). No significant differences were observed by sex. According to geographic area, 42.5% of school-age children who dropped out from the educational system lived in rural areas, whereas only 9.4% of those graduated from high school lived in such conditions ($P<0.001$). In the same way, dropout children were significantly older compared with the rest of the sample ($P<0.0001$). SA 1987 was significantly lower in dropout school-age children compared with their peers from the other groups ($P<0.0001$) and belonged mainly to public schools ($P<0.0001$). Graduated school-age children presented a percentage of SA 1987 higher than those from the other groups of the sample. They had not repeated any grade compared with their delayed and dropout peers ($P<0.0001$).

Logistic regression analysis between the educational situation of school-age children in 1998, dependent variable, categorized them as dropout and non-dropout groups, dropout and delayed groups and dropout and graduated groups (probability modelled was dropout = yes) (Table 5) revealed that SES, IA, SA and Z-HC were the independent variables at the onset of elementary school in 1987 with the greatest explanatory power of the educational situation in 1998. SES was selected in the first place in the statistical regression model and the odds ratio value (0.115) implies that high, medium-high and medium SES is a preventive factor that decreases in 88.5% the probability of dropping out. IA entered in the second place in the statistical regression model (odds ratio = 0.457) and is another preventive factor as IA Grades I, II and III decrease by 54.3% the probability of dropping out. As regards to SA and Z-HC, these

Table 2 Nutrient intake of Chilean school-age children at the onset of elementary school in 1987 by educational situation 1998[a]

Nutrient intake 1987	*Educational situation 1998*				F
	Not located (n = 181)	*Dropout (n = 73)*	*Delayed (n = 208)*	*Graduated (n = 351)*	
Nutrient intake					
Energy and protein					
Energy (kcal)	2396.6±717.3	2206.6±717.3	2209.4±717.2	2265.2±694.1	0.92 NS
Protein (g)	75.1a±27.3	59.6b±28.0	69.7a±25.2	73.6a±24.1	2.79*
Vitamins					
Vitamin A (μg RE)	797.4±2172.9	443.0±267.3	756.1±1684.5	558.4±740.9	0.79
Thiamin (mg)	1.7±0.7	1.6±0.7	1.6±0.6	1.6±0.6	0.93
Riboflavin (mg)	2.0a±1.4	1.3b±0.7	1.9a±1.2	1.8a±0.9	2.87*
Niacin (mg NE)	25.9a±10.9	19.3b±10.9	23.3ab±11.0	23.7ab±9.3	2.76*
Vitamin B_6 (mg)	1.0±0.9	0.9±0.7	0.9±0.5	1.0±0.5	1.27
Vitamin B_{12} (μg)	6.4 ±19.1	1.9 ±1.9	5.7 ±14.8	4.6 ±5.6	0.99
Folate (μg)	207.2±162.9	172.9±62.0	190.7±123.3	212.8±173.3	0.70
Pantothenic acid (mg)	3.8ab±2.1	2.9a±1.3	3.7ab±1.6	4.0b±1.7	3.22*
Ascorbic acid (mg)	85.2±80.5	71.1±55.2	87.8±71.0	97.1±94.9	
Minerals					
Calcium (mg)	882.4ab± 477.9	630.5b±439.4	878.2ab±466.4	922.5a±452.6	2.96*
Phosphorus (mg)	1232.6±457.3	1012.9±444.4	1206.6±470.5	1233.0±441.3	1.83
Iron (mg)	21.1±8.7	20.4±8.8	21.4±9.7	20.8±8.6	0.14
Zinc (mg)	7.2ab± 4.1	5.7b±3.2	6.6ab±2.8	7.7a±3.6	3.06*
Magnesium (mg)	214.2±152.5	208.6±139.7	195.5±99.9	233.2±148.5	1.27
Copper (mg)	0.8±1.2	0.7±0.4	0.7±1.0	0.6±0.6	0.43
Selenium (μg)	79.9±43.3	86.0±35.0	74.2±35.1	72.7±38.2	1.21
Percentage of adequacy					
Energy and protein					
Energy	140.7±43.1	126.4±45.3	128.1±43.8	133.5±42.5	1.21
Protein	186.8±67.6	151.9±84.2	181.4±66.5	184.7±64.6	1.72
Vitamins					
Vitamin A	152.3±419.7	82.0±54.9	150.5±337.0	110.4±147.4	0.78
Thiamin	192.3±73.3	173.5±70.4	174.8±63.0	178.8±66.0	0.96
Riboflavin	178.1a±125.3	113.5b±64.9	176.4ab±113.0	166.8ab±79.3	3.09*
Niacin	215.6a±90.6	157.1b±91.2	193.6ab±91.3	196.8ab±77.4	3.00*
Vitamin B_6	92.1±80.3	76.0±63.7	77.7±43.0	91.4±47.5	1.45
Vitamin B_{12}	613.4±1848.5	190.4±189.2	562.0±1482.7	453.1±559.0	0.94
Folate	271.7±215.0	211.4±80.2	252.5±164.5	281.6±231.5	1.02
Pantothenic acid	123.1ab±67.9	88.5a±41.9	122.5ab±52.8	132.6b±56.5	4.44**
Ascorbic acid	189.4±179.0	158.1±122.7	1495.2±157.9	215.7±211.0	0.86
Minerals					
Calcium	110.3ab±59.7	78.8b±54.9	109.8ab±58.3	115.3a±56.6	2.96*
Phosphorus	154.1±57.2	126.6±55.5	150.8±58.8	154.1±55.2	1.83
Iron	211.3±87.2	204.0±88.0	214.4±91.3	207.7±86.4	0.14
Zinc	72.2a±40.7	57.1b±31.7	65.9ab±28.2	76.5ab±36.1	3.06*
Magnesium	175.6±127.3	154.4±95.0	161.2±82.7	192.3±123.8	1.66
Copper	78.1±122.7	69.1±36.7	72.6±98.8	64.6±55.3	0.43
Selenium	391.5±216.3	376.5±146.4	368.1±175.6	358.9±190.2	0.45
Fatty acids and cholesterol					
% saturated	35.4ab±9.6	32.2a±10.8	34.8ab±10.5	37.9b±8.7	3.84*
% monounsaturated	36.1±5.3	36.6±5.8	38.1±6.4	36.8±5.3	1.58
% Polyunsaturated	28.5ab±10.3	31.2a±11.0	27.1ab±9.9	25.3b±8.1	3.86**
Cholesterol	204.6ab±175.3	136.6a±124.9	218.1ab±158.3	255.4b±195.3	3.87**
Energy sources					
% protein	12.4a±2.5	10.6b±2.6	12.5a±2.7	13.0a±2.7	6.17***
% fat	26.8ab±7.4	22.8a±8.3	27.7b±7.3	28.b±7.5	4.79**
% carbohydrates	60.8a±7.4	66.6b±9.3	59.8a±7.3	58.4a±8.4	8.21****
Protein sources					
% animal protein	46.7a±17.7	31.7b±16.5	46.4a±17.7	51.5a±16.6	10.21****

[a]Results are expressed as mean±s.d.
Means with the same letter are not significantly different at the 0.05 level based on Scheffe's test. *F*, variance.
**P*<0.05; ***P*<0.01; ****P*<0.001; *****P*<0.0001; NS: not significantly different.

Table 3 Socio-economic and socio-cultural variables of Chilean school age-children at the onset of elementary school in 1987 by educational situation 1998

Socio-economic and socio-cultural variables	*Educational situation 1998*				*Total sample (813)*	X_o^2 *or Fisher*
	Not located (n = 181)	*Dropout (n = 73)*	*Delayed (n = 208)*	*Graduated (n = 351)*		
			% of cases			
Socio-economic stratum						
High	10.5	1.4	12.0	29.6	18.3	X_o^2 (6) = 113.860 > X_t^2 (6) 0.001 = 22.457
Medium	36.5	11.0	38.0	41.0	36.5	
Low	53.0	87.6	50.0	29.4	45.2	
Total	100.0	100.0	100.0	100.0	100.0	
Household head schooling						
Illiterate	0.0	3.0	0.6	0.3	0.6	X_o^2 (12) = 98.686 > X_t^2 (12) 0.001 = 32.909. χ^2 test was calculated by joining the categories (illiterate + incomplete elementary school) and (incomplete + complete university education).
Incomplete elementary school	25.5	51.5	21.9	11.4	20.6	
Complete elementary school	10.4	12.1	10.9	8.6	9.9	
Incomplete high school	19.0	15.2	18.0	15.0	16.6	
Complete high school	31.4	16.7	34.4	31.9	31.0	
Incomplete university education	3.9	0.0	2.2	2.8	2.6	
Complete university education	9.8	1.5	12.0	30.0	18.7	
Total	100.0	100.0	100.0	100.0	100.0	
Maternal schooling						
Illiterate	2.5	1.5	0.0	0.3	0.8	X_o^2 (12) = 101.000 > X_t^2 (12) 0.001 = 32.909. χ^2 test was calculated by joining the categories (illiterate + incomplete elementary school) and (incomplete + complete university education).
Incomplete elementary school	28.6	54.4	23.0	16.4	24.2	
Complete elementary school	13.7	14.7	14.4	7.1	11.1	
Incomplete high school	19.2	19.1	21.4	18.6	19.5	
Complete high school	29.8	8.8	35.8	36.2	32.2	
Incomplete university education	2.5	0.0	0.0	2.8	1.8	
Complete university education	3.7	1.5	5.4	18.6	10.4	
Total	100.0	100.0	100.0	100.0	100.0	
Household head occupation						
1. Managerial positions	2.3	0.0	0.9	1.7	1.5	X_o^2 (6) = 115.381 > X_t^2 (6) 0.001 = 22.457. χ^2 test was calculated by join the categories (1 + 2) and (4 + 5 + 6).
2. Mid-level employee	13.0	2.8	14.9	32.8	21.2	
3. Specialized worker	42.6	16.7	41.4	43.6	40.4	
4. Non-specialized worker	34.7	69.4	38.9	19.4	32.2	
5. Jobless receiving state aid	4.0	8.3	3.4	1.9	3.4	
6. Jobless without state aid	1.1	1.4	0.0	0.0	0.4	
7. Housekeepers	2.3	1.4	0.5	0.6	0.9	
Total	100.0	100.0	100.0	100.0	100.0	

Table 3 *Continued*

Socio-economic and socio-cultural variables	*Educational situation 1998*				*Total sample (813)*	X_o^2 *or Fisher*
	Not located (n = 181)	*Dropout (n = 73)*	*Delayed (n = 208)*	*Graduated (n = 351)*		
Maternal occupation						
1. Managerial positions	0.0	0.0	0.0	0.3	0.1	X_o^2 (6) = 61.400 > X_t^2 (6) 0.001 = 22.457. χ^2 test was calculated by joining the categories (1 + 2 + 3) and (4 + 5).
2. Mid-level employee	1.7	0.0	1.9	7.5	4.1	
3. Specialized worker	11.8	2.7	12.6	18.6	14.1	
4. Non-specialized worker	17.0	19.2	10.6	3.4	9.7	
5. Jobless receiving state aid	1.7	2.7	1.5	0.3	1.1	
6. Jobless without state aid	0.0	0.0	0.0	0.0	0.0	
7. Housekeepers	67.8	75.4	73.4	69.9	70.9	
Total	100.0	100.0	100.0	100.0	100.0	
Quality of housing						
Single family unit	2.3	0.0	4.9	12.7	7.3	X_o^2 (12) = 102.065 > X_t^2 (12) 0.001 = 32.909.
Solid materials	12.8	1.4	10.3	22.2	15.3	
Light materials	48.3	29.6	48.3	41.5	43.6	
Self-built	25.0	52.1	30.1	20.8	26.9	
Precarious housing ('Mejora')	11.6	16.9	6.4	2.8	6.9	
Total	100.0	100.0	100.0	100.0	100.0	
Property of housing						
Owner	51.2	59.2	58.6	61.7	58.4	X_o^2 (6) = 24.168 > X_t^2 (6) 0.001 = 22.457. χ^2 test was calculated by joining the categories (usufructuary + entourage + squatter).
Tenant	30.8	12.7	21.2	27.1	25.0	
Usufructuary	4.7	4.2	2.0	1.7	2.7	
Entourage	11.6	23.9	18.2	9.5	13.5	
Squatter	1.7	0.0	0.0	0.0	0.4	
Total	100.0	100.0	100.0	100.0	100.0	
Sewerage						
With sewerage	84.9	62.0	89.7	92.8	87.5	X_o^2 (3gl) = 53.196 > X_t^2(3gl) 0.001 = 16.268.
Without sewerage	15.1	38.0	10.3	7.2	12.5	
Total	100.0	100.0	100.0	100.0	100.0	
Water supply						
With drinking water	94.8	93.0	98.5	98.9	97.4	Fisher = $P < 0.001$, calculated by joining not located + dropout and delayed + graduated.
Without drinking water	5.2	7.0	1.5	1.1	2.6	
Total	100.0	100.0	100.0	100.0	100.0	

parameters entered in the third and fourth places, respectively, in the statistical regression model. Those children who in 1987 attained SA scores ⩽ median (Md) (⩽62.5% of achievement) (odds ratio = 2.684) and those with Z-HC values ⩽Md (⩽0.175) (odds ratio = 2.317) increase their probabilities of dropping out by 168 and 131.7%, respectively; therefore, SA scores and Z-HC values ⩽Md are important risk factors for dropout. When comparing the dropout and delayed groups, again SES and IA appear as preventive factors and Z-HC as risk factor for dropping. Thus, high, medium-high and medium SES and IA Grades I, II and III are preventive factors that decreases in 84.9% (odds ratio = 0.151) and by 56.4% (odds ratio = 0.436) the probability of dropout, respectively. However, Z-HC is a risk factor

Table 4 Intellectual, demographic and educational variables of Chilean school-age children at the onset of elementary school in 1987 by educational situation 1998[a]

	Educational situation 1998				*Total sample (813)*
	Not located (n = 181)	*Dropout (n = 73)*	*Delayed (n = 208)*	*Graduated (n = 351)*	
		% of cases			
Intellectual variables					
Intellectual ability (IA)					
Grade I	3.0	0.0	0.5	9.9	5.1
Grade II	19.0	11.4	16.8	27.8	21.6
Grade III	40.5	30.0	48.8	39.7	41.3
Grade IV	27.4	34.3	22.6	15.9	21.8
Grade V	10.1	24.3	11.3	6.7	10.2
Total	100.0	100.0	100.0	100.0	100.0
$X_o^2\ (12) = 77.311 > X_t^2\ (12)\ 0.001 = 32.909$					
Demographic variables					
Sex					
Males	46.4	52.0	56.2	50.1	51.0
Females	53.6	48.0	43.8	49.9	49.0
Total	100.0	100.0	100.0	100.0	100.0
$X_o^2(3) = 3.966 < X_t^2(3)\ 0.05 = 7.815$					
Geographic area					
Urban	83.2	57.5	85.1	90.6	84.6
Rural	16.8	42.5	14.9	9.4	15.4
Total	100.0	100.0	100.0	100.0	100.0
$X_o^2(3) = 51.030 > X_t^2(3)\ 0.001 = 16.268$					
		Mean ± s.d. (years)			
Age	6.6ac ± 0.5	6.8b ± 0.7	6.5ac ± 0.4	6.5c ± 0.4	
$F = 10.9$ $P < 0.0001$					
Educational variables					
Scholastic achievement (SA) 1987					
		Mean ± s.d. (% of achievement)			
SA overall results (LA + MA)	56.5a ± 20.3	47.5b ± 17.4	56.9a ± 17.8	69.5c ± 17.7	44.58****
LA	44.3a ± 23.8	34.8a ± 21.8	43.8a ± 24.2	60.3b ± 24.2	38.83****
MA	68.6a ± 22.9	60.2b ± 20.7	69.9a ± 18.2	78.7c ± 17.2	25.42****
% of attendance 1987	90.7 ± 9.5	91.4 ± 6.8	91.0 ± 6.3	92.3 ± 6.0	2.46 (t)
Number of repeated grades between 1987 and 1998	—	0.7a ± 0.8	1.3b ± 0.6	0.0c ± 0.0	684.22 ****
		% of cases			
Type of school					
Public	58.1	60.2	45.2	32.8	44.0
Private subsidized	36.3	38.4	44.2	41.8	40.9
Private non- subsidized	5.6	1.4	10.6	25.4	15.1
Total	100.0	100.0	100.0	100.0	100.0
$X_o^2(6) = 42.654 > X_t^2\ (6)\ 0.001 = 22.457$					

[a]Means with the same letter are not significantly different at the 0.05 level based on Scheffe's test.
IA grades: Grade I, superior; Grade II, above average; Grade III, average; Grade IV, below average; Grade V, intellectually defective; LA, Spanish language achievement; MA, mathematics achievement.
****$P < 0.0001$; (t), tendency ($P > 0.05$ and < 0.01).

for dropout, as Z-HC values ≤Md (≤0.175) (odds ratio = 2.130) increase the probability of dropping out by 113%. SA did not enter in the statistical regression model. The comparison between dropout and graduated groups revealed that again high, medium-high and medium SES and IA Grades I, II and III are preventive factors that decrease by 91.3% (odds ratio = 0.087) and by 52.6% (odds ratio = 0.474) the probability of dropping out, respectively. SA and Z-HC are risk factors for dropping out as SA scores ≤median (Md) (≤62.5% of achievement) (odds ratio = 4.381) and those with Z-HC values ≤Md (≤0.175) (odds ratio = 2.766) increase their probabilities of dropping out by 338.1 and 176.6%, respectively; therefore, SA scores and Z-HC values ≤Md are important risk factors for dropout with the highest probabilities for dropping out compared with the other groups.

Table 5 Logistic regression between the educational situation 1998, dependent variable, categorized as dropout and non-dropout groups, dropout and delayed groups and dropout and graduated groups and most relevant parameters at the onset of elementary school in 1987 (independent variables)[a]

Parameters 1987 entered in the statistical model	*Effect*	*Wald χ^2*	*Odds ratio estimates*		
			Point estimate	*95% Wald confidence limits*	
Dropout and non-dropout groups					
1. SES	High + medium-high + medium vs medium-low + Low	26.2951****	0.115	0.050	0.263
2. IA	Grades I+II+III vs Grades IV+V	7.0401**	0.457	0.257	0.815
3. SA	⩽Md vs>Md	6.8420**	2.684	1.281	5.624
4. Z-HC	⩽Md vs>Md	6.2026*	2.317	1.196	4.490
Dropout and delayed groups					
1. SES	High + medium-high + medium vs medium-low + low	18.9140 ****	0.151	0.064	0.354
2. IA	Grades I+II+III vs Grades IV+V	6.7365 **	0.436	0.232	0.816
3. Z-HC	⩽Md vs >Md	4.3764 *	2.130	1.049	4.325
Dropout and graduated groups					
1. SES	High + medium-high + medium vs medium-low + low	31.6095****	0.087	0.037	0.204
2. IA	Grades I+II+III vs Grades IV+V	4.9982*	0.474	0.247	0.912
3. SA	⩽Md vs > Md	13.8481***	4.381	2.012	9.539
4. Z-HC	⩽Md vs > Md	7.7186**	2.766	1.349	5.671

[a]Probability modeled was dropout = yes.
SES, socio-economic stratum; IA, intellectual ability; IA grades: Grade I, superior; Grade II, above average; Grade III, average; Grade IV, below average; Grade V, intellectually defective; SA, scholastic achievement; Md, median; Md SA, 62.5 % of achievement; Z-HC, head circumference-for-age *Z* score; Md Z-HC, 0.175. $n = 632$.
*$P<0.05$; **$P<0.01$; ***$P<0.001$; ****$P<0.0001$.

Discussion

Of the original sample, 77.7% (632 school-age children) were located in 1998; this proportion or more was located in each stratum sample relating to geographic area, sex and type of school. The educational situation of the school-age children detected in 1998 who had been members of the original sample of school-age children enrolled in first grade of elementary school in 1987 was as follows: 43% of school-age children graduated from high school, 26% experienced school delay, 9% dropped out from the educational system and 22% could not be located (Ivanovic, 2003). The main causes of dropout were low SA (24%), personal problems (18%), pregnancy (35% of the females), socio-economic difficulties (10%), health problems (8%) and lack of interest about school (8%). Most of the dropouts occurred at the onset of adolescence, when they should have enrolled in the first year of high school (28%), followed by the eighth grade of elementary school (25%) and in the second year of high school (22%). A lesser percentage of school-age children, 14%, dropped out between the fifth and the seventh grades of elementary school, 9.6% between the first and the fourth grade of elementary school and only 1.4% between the third and the fourth years of high school (Ivanovic, 2003).

This study represents the only one of its kind carried out in Chile, and focuses on the educational situation of school-age children along the educational system. Our results demonstrate that the educational situation along the school years is conditioned by socio-economic, educational, intellectual and nutritional variables at the onset of elementary school, and show that the educational situation of children is a multicausal problem.

Socio-economic conditions appear as the most relevant factor affecting the educational situation mainly when comparing dropout and graduated groups. This is explained by the negative consequences of poverty for child development, family structure, including the child's environment, nutritional status, intellectual functions and educational success. This is clearly manifested in the present study as most of the dropouts and delayed school-age children belonged, at the onset of elementary school, to the low SES (87.6 and 50.0%, respectively) and had low SA associated with low IA and a more deteriorated nutritional status (Singh and Arvind, 1986; Ivanovic 1988, 2003; Ivanovic *et al.*, 1988, 2000a, b, c, 2001, 2002; Ivanovic and Ivanovic, 1990; Kramer *et al.*, 1995; Brown and Pollitt, 1996).

Intelligence is the most relevant parameter that explains both SA and the results of the SA test for university admission and in the present study contributed to explain the educational situation in 1998 (Ivanovic *et al.*, 2000a, b, 2002, 2004b, c, 2006). Our results show that school-age children graduating from high school in 1998 already had IA grades significantly higher than their dropout peers in 1987. On the other hand, the maternal intellectual quotient, child brain volume and the presence of undernutrition during the first year of life have been described as the most relevant parameters that explain the child's intellectual quotient and in turn only the intellectual quotient explained SA variance (Ivanovic *et al*., 2000a, b, 2002).

As regards SA, already in 1987, dropout children scored approximately 20 points below their peers who graduated in 1998 in overall results as well as in LA and MA and this could indicate that SA at the onset of elementary school is a good predictor of school dropout. Children with low SA in 1987 had the probability of having dropping out increased by 338% when compared with their graduated peers. These findings are in agreement with those from other investigators who reported that at the onset of elementary school, school experiences as test scores, marks and track placements are precursors to high school desertion (Alexander *et al*., 1997).

HC in 1987 is the only anthropometric indicator of both nutritional background and brain development associated with the educational outcome 1998 (absolute or adjusted for height). Thus, some anthropometric indicators of past nutrition may be relevant to explain differences in the educational situation of school-age children. Similar results were observed when quantitating the impact of the nutritional status upon SA and IA assessed through the Raven Progressive Matrices Test, HC being the most important anthropometric parameter (Ivanovic *et al*., 1996, 2000b; Toro *et al*., 1998). It has been defined as the most sensitive anthropometric marker of prolonged undernutrition during infancy, associated with decreased SA and IA (Stoch *et al*., 1982; Ivanovic *et al*., 2000b, 2004a, b, c).

Our results emphasize that the educational situation of school-age children is a multicausal problem as the most relevant parameters that explain it are positively and significantly interrelated. School-age children from the low SES achieve significantly lower in SA and intelligence tests and tend to have a negative nutritional background manifested mainly through a smaller HC compared to their peers from the higher socio-economic strata (Singh and Arvind, 1986; Ivanovic 1988; Ivanovic and Ivanovic, 1990; Ivanovic *et al*., 1995a, 1996, 2000a, b, c, 2001, 2002, 2004a, b, c; Kramer *et al*., 1995; Brown and Pollitt, 1996; Toro *et al*., 1998).

Dropping out from the educational system is related to HC but not with weight or height (Ivanovic *et al*., 1996). From the results presented here, we may hypothesize that children with suboptimal HC may have alterations of brain development which become associated with the lowered SES, SA and IA, variables that in the current study contributed to determine the educational results; independent of SES and sex, differences in human brain size are relevant to explain differences in intelligence test performance (Ivanovic *et al*., 1996, 2000a, b, c, 2001, 2002, 2004a, b, c; Reiss *et al*., 1996; Botting *et al*., 1998; Strauss and Dietz, 1998; Toro *et al*., 1998; Pennington *et al*., 2000). These studies found positive and significant correlations between HC, SA, IA, brain and parental HC; however, an absence of correlations between brain size, HC and intelligence has been reported in studies of monozygotic twins or in sisters (Tramo *et al*., 1998; Schoenemann *et al*., 2000). Other studies have concluded that head size at an early age is a good predictor of later intelligence, learning, cognition and concentration at school age (Botting *et al*., 1998; Strauss and Dietz, 1998; Stathis *et al*., 1999).

Our results underline that socio-economic conditions, SA, IA and HC at the onset of elementary school are good predictors of later educational situation along the educational system. These variables at the time when school-age children enrol in the first grade of elementary school may predict educational evolution along the educational system and are significantly interrelated. It is probably that the better socio-economic conditions of graduated students may have contributed to determine a significantly higher SA, IA and nutritional status (mainly HC) compared with delayed and dropout school-age children. However, it is necessary to comment about other characteristics at the onset of elementary school in 1987 of the dropout students that might have influenced them in the school desertion. When they attended to the first grade of elementary school, they were significantly older than the other groups of the sample, already evidencing a school delay; most of them lived in rural areas, attended the public school system, had higher incidences of undernutrition, growth failure and suboptimal HC and inadequate nutrient intakes, especially of calcium and zinc and read books significantly less than their delayed and graduated peers. By 1998 they had to repeat more school courses than the other groups. It is well known that the type of school children attend encompasses other variables related to the educational system such as teacher's training and professional experience, educational infrastructure and methodologies; therefore, private non-subsidized schools provide their pupils the best quality of education, because they exhibit an adequate infrastructure, engage teachers with better professional experience, that apply modern teaching methodologies. Even more, private non-subsidized schools enrolled school-age children from high SES, with superior IA, whose parents have higher paid jobs and schooling levels, with higher Z-HC, Z-H values and nutrient intakes and with higher availability of written MM (Ivanovic and Ivanovic, 1990; Ivanovic *et al*., 1995b, 2001). However, the results of the present study showed that the type of school did not contribute to explain educational situation. This is in agreement with a previous report that revealed that the type of school is a less important independent variable that affects SA (Ivanovic *et al*., 2004c). This is important as educational policies tend to improve conditions related to the educational system that, although they are important, are not the most relevant among those that affect SA.

This is surprising because educational policies tend to improve the conditions related to the educational system that are very important but not the most relevant variables that are affecting school dropout.

In Latin America, during the last decades educational policies have successfully expanded the educational systems with the aim of providing access to education to the greatest number of school-age children. In Latin American and Caribbean countries SES conditions, especially maternal schooling, have been identified as one of the most important determinants of SA (UNESCO, 1994). Other investigations demonstrated that maternal schooling is the most important socio-cultural variable that explains SA and IA (Ivanovic *et al.*, 1995b, 2001). In this study, dropout school-age children had mothers with the lowest schooling levels but global SES was the most important variable explaining the student's educational situation in 1998.

In summary, our findings confirm that the educational situation in 1998 could be positively and significantly associated with the prevailing socio-economic conditions, IA, SA and a negative nutritional background manifested by a decreased HC at the onset of elementary school. Dropout was especially higher at the onset of adolescence when children finished elementary school and enrolled in the first grade of high school, probably because they did not fulfil the requirements related to SES, intelligence, educational and nutritional conditions necessary to succeed. As regard, it is possible that other environmental and genetic factors, which were not quantitated in our study, could also affect the educational situation of school-age children. Further research can be needed to provide forward evidence to this multicausal problem in which research is scarce both in Chile and in other countries.

Successful and unsuccessful children manifested early differences related to SES, intelligence, SA and nutritional status; however, it should be kept in mind that none of these imply determinism. The dropout group exhibited the higher percentage of disadvantaged children and this is an attention call about the low capacity of schools to take advantage of the talents that all children have. The educational system, mainly in developing countries, has not developed a degree of organization adequate to provide remedial help to the more deprived children. Taking into account these findings, an integrated plan for vocational guidance of school-age children within a multicausal context may be a useful initiative to stimulate disadvantaged children according to their capacities.

Acknowledgements

This study was supported in part by Grants S 2169-924F and EO11-97/2 from the University of Chile, Research Department (DI), by Grants 1841167 and 1880818 from the National Fund for Scientific and Technologic Development (FONDECYT) and by Grant 019/1997 from the University of Chile, Postgradest Department. Authors are very gratefully to the Ministry of Education of Chile for all the facilities given to carry out this research; to Dr. Oscar Brunser MD, for helpful comments and suggestions. The data for the present manuscript are part from a thesis submitted by the second author María del Pilar N Rodríguez, in partial fulfilment of the requirements for the Master of Nutritional Sciences degree from the Institute of Nutrition and Food Technology (INTA), University of Chile.

References

Alexander K, Entwisle D, Horsey C (1997). From first grade forward: early foundations of high school dropout. *Sociol Educ* **70**, 87–107.

Alvarez ML, Muzzo S, Ivanovic D (1985). Escala para medición del nivel socioeconómico en el área de la salud. *Rev Med Chil* **113**, 243–249.

Botting N, Powls A, Cooke RW, Marlow N (1998). Cognitive and educational outcome of very low-birth weight children in early adolescence. *Dev Med Child Neurol* **40**, 652–660.

Brown L, Pollitt E (1996). Malnutrition, poverty and intellectual development. *Sci Am* **274**, 38–43.

Chile. Ministerio de Educación Pública (1980). Planes y Programas para la Educación General Básica. *Rev Educ* **79**, 9–73.

Chile. Ministerio de Educación Pública (1987). *Estadísticas educacionales*. Superintendencia de Educación: Santiago.

FAO/OMS/UNU (1985). *Energy and protein requirements* World Health Organization. Technical Report Series N° 724 WHO: Ginebra.

Food and Nutrition Board (2000a). *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. The National Academies Press: Washington DC.

Food and Nutrition Board (2000b). *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. The National Academies Press: Washington DC.

Food and Nutrition Board (2000c). *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. The National Academies Press: Washington DC.

Food and Nutrition Board (2002). *Dietary reference intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, vanadium, and zinc*. The National Academies Press: Washington DC.

Frisancho AR (1981). New norms of upper limb fat and muscle areas for assessment of nutritional status. *Am J Clin Nutr* **34**, 2540–2545.

Gibson R (1990). *Principles of Nutritional Assessment*. Oxford University Press: Oxford.

Guilford JP, Fruchter B (1984). *Estadística Aplicada a la Psicología y a la Educación*. McGraw Hill: México.

Hrimech M, Theoret M (1997). High school dropout: a comparison between montreal students born in canada and abroad. *Can J Educ* **22**, 268–282.

Ivanovic D (2003). Características de los alumnos asociadas a su trayectoria escolar. In: En Belleï C, Fiabiane F (eds.) *12 años de escolaridad obligatoria*. LOM-PIIE-UNICEF: Santiago. pp 119-126.

Ivanovic D, Almagià A, Toro T, Castro C, Pérez H, Urrutia MS *et al.* (2000a). Impacto del estado nutricional en el desarrollo cerebral, inteligencia y rendimiento escolar, en el marco de un enfoque multifactorial. *La Educación (Organización de los Estados Americanos, OEA)* **44**, 3–35.

Ivanovic D, Forno H, Ivanovic R (2001). Estudio de la capacidad intelectual (Test de Matrices Progresivas de Raven) en escolares de 5 a 18 años. II. Interrelaciones con factores socioeconómicos, socioculturales, familiares, de exposición a medios de comunicación de masas, demográficos y educacionales. *Rev Psicol Gen Apl* **54**, 443–466.

Ivanovic D, Leiva B, Pérez H, Almagià A, Toro T, Urrutia MS *et al.* (2002). Nutritional status, brain development and scholastic achievement of Chilean high school graduates from high and low intellectual quotient and socio-economic status. *Br J Nutr* **87**, 81–92.

Ivanovic D, Leiva B, Pérez H, Inzunza N, Almagià A, Toro T *et al.* (2000b). Long-term effects of severe undernutrition during the first year of life on brain development and learning in Chilean high school graduates. *Nutrition* **16**, 1056–1063.
Ivanovic D, Leiva B, Pérez H, Olivares M, Díaz N, Urrutia MS *et al.* (2004b). Head size and intelligence, learning, nutritional status and brain development. *Neuropsychologia* **42**, 1118–1131.
Ivanovic D, Olivares M, Castro C, Ivanovic R (1995a). Circunferencia craneana de escolares chilenos de 5 a 18 años. Región Metropolitana de Chile. 1986–1987, 1992. *Rev Med Chil* **123**, 587–599.
Ivanovic D, Olivares M, Castro C, Ivanovic R (1996). Nutrition and learning in Chilean school-age children. Chile's Metropolitan Area. Survey 1986–1987. *Nutrition* **12**, 321–328.
Ivanovic D, Pérez H, Leiva B, Almagià A, Urrutia MS, Larraín C *et al.* (2006). Neuropsychological parameters affecting the Academic Aptitude Test (AAT) achievement at the end of high school in 1996 and their impact on job status in 2002: A multifactorial approach in a follow-up study. In: Joshua R. Dupri (Ed.) *Progress in Neuropsychology Research*. Nova Science Publishers: New York. pp 103–140.
Ivanovic D, Pérez H, Olivares M, Díaz N, Leyton B, Ivanovic R (2004c). Scholastic achievement: a multivariate analysis of nutritional, intellectual, socio-economic, socio-cultural, family and demographic variables in Chilean school-age children. *Nutrition* **20**, 878–889.
Ivanovic D, Zacarías I, Saitúa MT, Marambio M (1988). Educational achievement and nutritional status of elementary and high school graduates. In Moyal MF (Ed.) *Dietetics in the 90s. Role of the Dietitian/Nutritionist*. John Libbey Eurotext Ltd: London. pp 331–334.
Ivanovic DM, Leiva BP, Castro CG, Olivares MG, Jansana JM, Castro V *et al.* (2004a). Brain development parameters and intelligence in Chilean high school graduates. *Intelligence* **32**, 461–479.
Ivanovic R (1988). Factores socioeconómicos, socioculturales y sociopsicológicos que inciden en el rendimiento escolar. En Ivanovic D, Ivanovic R, Middleton S (eds.) *Rendimiento escolar y estado nutricional*. Universidad de Chile, INTA: Santiago. pp 7–9.
Ivanovic R, Castro C, Ivanovic D (1995b). No existe una teoría sobre el rendimiento escolar. *Rev Educ (Ministerio de Educación de Chile)* **224**, 40–45.
Ivanovic R, Forno H, Castro CG, Ivanovic D (2000c). Intellectual ability and nutritional status assessed through anthropometric measurements of Chilean school-age children from different socio-economic status. *Ecol Food Nutr* **39**, 35–59.
Ivanovic R, Forno H, Durán MC, Hazbún J, Castro C, Ivanovic D (2000d). Estudio de la capacidad intelectual (Test de Matrices Progresivas de Raven) en escolares de 5 a 18 años. I. Antecedentes generales, normas y recomendaciones. Región Metropolitana. Chile. 1986–1987. *Iberpsicología* 2003; 8.1.1. (Versión completa del trabajo aparecido en Rev *Psicol Gen Apl (España)* **53**, 5–30).
Ivanovic R, Ivanovic D (1990). Características socioeconómicas, socioculturales, familiares y demográficas de estudiantes de Educación Básica y Media (Región Metropolitana de Chile 1986–1987). *Rev Sociol* **5**, 183–201.
Ivanovic R, Sepúlveda O (1988). Rendimiento escolar y exposición a medios de comunicación de masas en estudiantes de enseñanza media del Área Metropolitana. *Rev Sociol* **3**, 73–87.
Kaplan DS, Damphousse KR, Kaplan HB (1994). Mental health implications of not graduating from high school. *J Exp Educ* **62**, 105–123.
Kaplan DS, Peck BM, Kaplan HB (1995). A structural model of dropout behavior: A longitudinal analysis. *Appl Behav Sci Rev* **3**, 177–193.
Kramer R, Allen L, Gergen P (1995). Health and Social Characteristics and Children's Cognitive Functioning: Results from a National Cohort. *Am J Public Health* **85**, 312–318.
National Center for Health Statistics (2000). *Growth curves, 2000*. US Department for Health and Human Services, National Center for Health Statistics: Hyattsville, Maryland. (From the Vital and Health Statistics of the National Centers for Disease Control and Prevention, National Center for Health Statistics, Number 314, December 4).
Nellhaus G (1968). Head circumference from birth to eighteen years. Practical composite international and interracial graphs. *Pediatrics* **41**, 106–114.
Pennington BF, Filipek PA, Lefly D, Chhabildas N, Kennedy DN, Simon JH *et al.* (2000). A twin MRI study of size variations in human brain. *J Cogn Neurosci* **12**, 223–232.
Pollitt E (1983). Evaluación de la conducta en los estudios sobre las consecuencias funcionales de la malnutrición. Descripción de métodos. En OPS/OMS (ed.) *Ambiente, nutrición y desarrollo menta*, Publicación científica No 450 OPS/OMS: Washington. pp 58–74.
Pollitt E, Cueto S, Jacoby ER (1998). Fasting and cognition in well- and undernourished schoolchildren: a review of three experimental studies. *Am J Clin Nutr* **67**, 779S–784S.
Pollitt E, Mathews R (1998). Breakfast and cognition: an integrative summary. *Am J Clin Nutr* **67**, 804S–813S.
Pong SL, Ju DB (2000). The effects of change in family structure and income on dropping out of middle and high school. *J Fam Issues* **21**, 147–169.
Raven JC (1957). *Test de Matrices Progresivas. Escala Especial*. Buenos Aires: Paidos.
Reiss Al, Abrams MT, Singer HS, Ross JL, Denckla MB (1996). Brain development, gender and IQ in children. A volumetric imaging study. *Brain* **119**, 1763–1774.
Roche AF, Mukherjee D, Guo S, Moore W (1987). Head circumference reference data: birth to 18 years. *Pediatrics* **79**, 706–712.
Roderick M (1994). Grade, retention and school dropout: Investigating the Association. *Am Educ Res J* **31**, 729–759.
SAS (1983). *SAS Introductory Guide Statistics*. SAS Institute Inc: North Caroline.
Schmidt-Hebbel H, Pennacchiotti M, Masson L, Mella MA (1990). *Tabla de composición química de alimentos chilenos*. Universidad de Chile, Facultad de Ciencias Químicas y Farmacéuticas: Santiago.
Schoenemann PT, Budinger T, Sarich V, Wang W (2000). Brain size does not predict general cognitive ability within families. *Proc Natl Acad Sci USA* **97**, 4932–4937.
Singh S, Arvind K (1986). Relative Importance of Social Deprivation, Intelligence, Punctuality and Ethnicity in Predicting Educational Achievement. *Psychologia* **29**, 176–181.
Stathis SL, O'Callaghan M, Harvey J, Rogers Y (1999). Head circumference in ELBW babies is associated with learning difficulties and cognition but not ADHD in the school-aged child. *Dev Med Child Neurol* **41**, 375–380.
Stevenson W, Maton KI, Teti DM (1998). School importance and dropout among pregnant adolescents. *J Adolesc Health* **22**, 376–382.
Stoch MB, Smythe PM, Moodie AD, Bradshaw D (1982). Psychosocial outcome and CT findings after gross undernourishment during infancy: a 20-year developmental study. *Dev Med Child Neurol* **24**, 419–436.
Strauss RS, Dietz WH (1998). Growth and development of term children born with low birth weight: effects of genetic and environmental factors. *J Pediatr* **133**, 67–72.
Tanner JM (1984). Physical growth and development. In Forfar JO, Arneil GC (Eds.) *Text book of Pediatrics*. Churchill Livingstone: Edinburgh. pp 278–330.
The World Medical Association (1964). Human experimentation. Code of Ethics of the World Medical Association (Declaration of Helsinki). *Br Med J* **2**, 177.
Toro T, Almagià A, Ivanovic D (1998). Evaluación antropométrica y rendimiento escolar en estudiantes de educación media de Valparaíso, Chile. *Arch Latinoam Nutr* **48**, 201–209.
Tramo MJ, Loftus WC, Stukel TA, Green RL, Weaver JB, Gazzaniga MS (1998). Brain size, head size, and intelligence in monozygotic twins. *Neurology* **50**, 1246–1252.
UNESCO (1994). *Medición de la calidad de la educación básica: resultados de siete países*. UNESCO-OREALC-REPLAD: Santiago.