Annals of Human Biology
Journal of the Society for the Study of Human Biology

http://informahealthcare.com/ahb
ISSN: 0301-4460 (print), 1464-5033 (electronic)

Ann Hum Biol, Early Online: 1–6

DOI: 10.3109/03014460.2013.841288

informa healthcare

RESEARCH PAPER

Association between childhood obesity, cognitive development, physical fitness and social-emotional wellbeing in a transitional economy

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Abstract

Background: It has been suggested that obese children have lower cognitive function, demonstrate poorer physical performance and are more susceptible to social-emotional problems.
Aims: To describe associations between human physical growth, cognitive development, physical fitness and social-emotional characteristics of obese and non-obese children and to verify the predictors of intellectual coefficient by socioeconomic status (SES).
Subjects and methods: A sample of 107 non-obese (N-Ob) children [-1 *z*-score body mass index (BMI) ≤ 1 *z*-score] and 108 obese (Ob) children [2 *z*-score $\leq$BMI ≤ 5 *z*-score] from a larger cohort was evaluated. Intellectual coefficient (IQ), social-emotional wellbeing (SEW), 6-minute walk test (6MWT) and SES (mid-low, low and very low) were assessed.
Results: Ob children were taller, heavier and present more height for age and BMI than N-Ob children ($p < 0.001$). A significant correlation between IQ and SEW ($r = 0.14$), 6MWT and BMI *z*-score ($r = -0.18$) and 6MWT and SEW ($r = 0.15$) was found. Multiple regression analysis revealed that BMI *z*-score had a negative impact on IQ in the mid-low SES sub-group and that SEW had a positive effect on IQ in the very-low SES sub-group.
Conclusions: In Chilean pre-school children from low-income families cognitive ability varied according to SES.

Keywords

Child health, psychosocial development, socioeconomic status

History

Received 8 November 2011
Revised 2 August 2013
Accepted 28 August 2013
Published online 11 October 2013

Introduction

High rates of childhood overweight and obesity in both developed and developing countries are generating a global public health crisis (Lobstein et al., 2004), with a potential impact on human capital development (Cawley & Spiess, 2008). There is evidence for a strong relationship between cognitive, emotional and physical development during early childhood and this can affect wellbeing and productivity in adult life (Diamond, 2007).

Several studies of intellectual performance have shown that obese individuals have a relative disadvantage when compared to non-obese individuals (Elias et al., 2003). Obesity was found to be inversely related to intelligence test scores in adolescents, even after adjusting for socioeconomic level (Sorensen et al., 1983). A case-control study showed a lower overall intelligence in overweight children (Li, 1995). In addition, obesity in early life can influence skeletal and muscle development, which can lower performance in motor function and physical exertion tests (Wearing et al., 2006) and impair motor development (Graf et al., 2004).

Social-emotional wellbeing in childhood contributes to shaping behaviour later in life; obese children are often stigmatized and are susceptible to suffering isolation, low self-esteem, depression and anxiety (Puhl & Brownell, 2003). Studies in pre-school children have shown a significant association between overweight and behavioural problems, with low socioeconomic status (SES) being a strong predictor of these problems (Datar & Sturm, 2004; Sawyer et al., 2006). Poverty is a powerful determinant of child development (Hackman & Farah, 2009). Children living in poverty receive less cognitive stimulation at home (Andrade et al., 2005), so may show decreased attention span, poor memory and weaker learning skills (Petterson, 2001), all of which influence cognitive development (Diamond, 2007). These mechanisms are likely at play in both obese and normal-weight children (Reilly, 2005).

In recent decades Chile has improved its economic situation (Agostini et al., 2008). Concomitantly, under-nutrition (weight for age <2 SD) and micronutrient deficiencies in children have been virtually eradicated (Mönckeberg, 2003). Presently, the mean height among children at 6 years is close to international standards (Kain et al., 2005).

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Today, the main nutritional problem of Chilean children is the rising prevalence of obesity, especially in low-income groups (Kain et al., 2005). The prevalence of obesity in children aged less than 6 years increased from less than 5% in 1980 to 7% in 1987 and over 21% in 2010 (Chilean National Board for School Assistance and Scholarships, 2011). However, despite improvements in nutritional status, a recent national survey indicates that almost a third of Chilean pre-school children exhibit developmental delays (Chilean Health Ministry, 2007). Thus, the aims of this study were to describe associations between human physical growth, cognitive development, physical fitness and social-emotional characteristics of obese and non-obese children and to verify the predictors of intellectual coefficient (IQ) by socioeconomic status (SES).

Methods

Population and sample

Data are from a sub-sample of Chilean pre-school children who participated in the Child Growth and Obesity Cohort Study. Total sample size comprises 1089 subjects, aged 4–5 years. The children were born in 2002–2003 with a gestational age between 37–42 weeks and a birth weight >2500 g. Participants with psychological conditions that could affect growth were not eligible for the study. Data were collected in day care centres of the National Nursery Schools Council Program (JUNJI) in Santiago, Chile, 2006 (National Board of Preschools, 2008).

In this study, all obese (Ob) children [2 z-score $\leq$BMI $\leq$5 z-score] (World Health Organization, Multicenter Growth Reference Study Group, 2006) ($n = 115$) were invited to participate in November 2007. An equal number of non-obese (N-Ob) children (-1 z-score $\leq$BMI $\leq$1 z-score) matched by age and sex was used as a comparison group. We excluded 15 children who did not meet the inclusion criteria: five children >6 years; two with an Apgar score <7 at 5 minutes of life; and eight with implausible anthropometric values at 5 years [weight-for-age (WA) $\leq$-6 z-score or $\geq$5 z-score; height-for-age (HA) $\leq$-6 z-score or $\geq$6 z-score and BMI $\leq$-5 z-score or $\geq$5 z-score]. The final sample comprised 107 N-Ob and 108 Ob children with a mean age of 5 years. Assuming 0.80 power, a two-tail significance level of 0.05 and SD = 15 for IQ, a sample size of 106 per group is required to detect a difference of five IQ points between Ob and N-Ob (Cohen, 1997). The study protocol was approved by the Executive Director of JUNJI and the Human Research Ethics Committee of the Institute of Nutrition and Food Technology (INTA). Written informed consent was obtained from all parents or guardians.

Anthropometric evaluation

Two trained evaluators assessed the children's weight and height using standardized procedures; reliability of measurements between observers was confirmed using the intra-class correlation coefficient ($R \geq 0.75$). Weight was measured with a portable electronic scale (Seca 770) with a precision of 0.1 kg and height was measured with a portable stadiometer (SECA 202) to the nearest 0.1 cm. BMI z-scores and HAZ for children were calculated using Anthro program (World Health Organization, 2007). BMI z-scores were analysed as both a continuous and categorical (Ob and N-Ob) independent variable.

Wechsler pre-school and primary scale of intelligence

Intellectual coefficient (IQ) was determined using the Wechsler Pre-school and Primary Scale of Intelligence (WPPSI-R). The Wechsler scale uses a mental test to explore individual differences (Sternberg & Kaufman, 1998). The WPPSI-R is a highly reliable instrument, with average estimates of reliability for the verbal IQ, performance IQ and full-scale IQ of 0.95, 0.92 and 0.96, respectively (Wechsler, 1989). The verbal scale tests used were information, comprehension, arithmetic, vocabulary and similarities. Performance scale tests included picture completion, picture arrangement, block design, digit symbol and object assembly. Two trained psychologists applied these tests; both had extensive previous training and experience in applying these tests to young children. Each child was evaluated in the classroom at the school. For data analysis, total IQ score was treated as a continuous variable.

Six-minute walk test

Physical fitness was assessed through the 6-minute walk test (6MWT). A professional trainer evaluated each child separately. Children were checked prior to testing to ascertain that they had not been fasting, had not consumed any food or liquid 30 minutes prior to the test, had not participated in vigorous exercise for at least 2 hours prior and had no known respiratory illnesses that could affect the results of the evaluation (i.e. allergic response or asthma). They were instructed to walk as fast as possible and complete the greatest number of laps during 6 minutes on a 30-metre circuit in the school yard, as described in the American Thoracic Society (2002) protocol. Heart rate (HR) was measured in beats per minute (BPM) using a digital stopwatch (Q 8Q Stopwatch) at three points in time: pre-test (after a 3-minute rest prior to taking the test), post-test (no more than 15 seconds after completion of the test) and recovery (at rest, 1 minute after completion of the test). Total distance walked (TD) and change in heart rate from pre- to post-test (ΔHR) values were considered as continuous variables.

Social-emotional wellbeing

The self-reported social wellbeing (SEW) test was used to evaluate adaptation of children to the educational environment. This instrument has been validated for Chilean children of the same age and sex as those in this sample (Lira et al., 2004). SEW consists of 22 items and evaluates seven dimensions: (1) adaptation to tasks, (2) social adaptation, (3) assertiveness, (4) self-esteem, (5) independence and personal autonomy, (6) optimism and (7) emotional response. The SEW was applied by a trained psychologist individually to each child in a private room. SEW score was treated as a continuous variable.

Socioeconomic status

The SES of pre-schoolers was determined using an economic index based on the presence or absence of 10 household items (colour TV, shower with hot water, refrigerator, washing machine, microwave oven, cellular phone with a monthly plan, cable TV, computer, internet and automobile) and the level of education of the main provider in the household. This socioeconomic framework has been widely used in Chile (Adimark, 2000; Amigo et al., 2012).

A trained sociologist collected the information through a face-to-face interview with each mother. Since all of the children belonged to low-income families, three socioeconomic groups were defined: mid-low (university, +8–10 goods), low (high school, +5–7 goods) and very-low SES (elementary school, +1–4 goods). For data analysis, SES was treated as a categorical variable.

Data analysis

Exploratory data analysis was carried out and the normal distribution of variables was evaluated using the Shapiro–Wilk test. Data of characteristics and main outcomes of groups are presented as mean and standard deviation (SD). We chose the Mann–Whitney test to assess the differences of means between groups (Ob and N-Ob) and the Kruskal–Wallis test for multiple group comparisons. An np-trend test was used to test for linear trends across the socioeconomic categories. Logistic discriminant analysis of household resources and education of main provider was conducted for detecting the variance explained within each SES category. Pearson correlation was applied to explore all possible associations between IQ, 6MWT, BMI and SEW.

Multiple linear regression analysis (MLRA) was used to define the effect of BMI *z*-score, 6MWT and SEW on IQ for N-Ob and Ob pre-school children, using age and sex as control variables. Interactions among variables were tested and a significant interaction was found for SES and BMI *z*-score ($p < 0.05$), so that we conducted MLRA for each SES category. Validation of the MLRA was based on exploring random distribution of the residual outcomes; normality was tested by Shapiro–Wilk and the normal distribution of the residuals was plotted. Significance was defined as a p value <0.05. All analyses were carried out in Stata 10 (Stata Corporation, College Station, TX) (StataCorp LP, 2007).

Results

Descriptive statistics (means and standard deviations) of non-obese and obese pre-school Chilean children are presented in Table 1. Final results were obtained for 215 pre-school children and no statistically significant differences were observed. Ob children were taller, heavier and presented more height-for-age and BMI than N-Ob children ($p < 0.001$). Comparing N-Ob and Ob children, significant differences were found in the 6MWT and AHR. N-Ob children walked a greater distance (21.9 metres) and had lower ΔHR (2.6 BPM less) than Ob children ($p < 0.01$).

The logistic discriminant analysis of household resources and education level of the main provider confirmed that the socioeconomic categorization was adequate; more than 86% of the variance was explained within each SES category. The distribution was as follows: 22.3% of families were classified as mid-low SES, 40.5% as low SES and 37.2% as very-low SES (data not shown).

Table 1. Characteristics and main outcomes of non-obese and obese Chilean pre-school children.

Variables	Non-obese ($n = 107$) $M \pm SD$	Obese ($n = 108$) $M \pm SD$	p Value
Age (months)	61.96 ± 4.53	60.95 ± 4.72	0.109
Height (cm)	109.23 ± 4.26	112.34 ± 4.89	0.001*
Weight (kg)	18.72 ± 1.76	26.59 ± 3.51	0.001*
Height for age (*z*-score)	-0.26 ± 0.79	0.49 ± 0.89	0.001*
BMI (*z*-score)	0.26 ± 0.48	3.16 ± 0.78	0.001*
WPPSI-R (IQ)	92.00 ± 8.94	91.69 ± 8.57	0.725
6MWT (metres)	521.77 ± 60.39	499.87 ± 53.00	0.006*
Δ Heart rate (ΔHR)	19.03 ± 6.65	21.65 ± 7.07	0.013*
SEW (score)	18.45 ± 2.70	17.81 ± 3.11	0.164

*$p < 0.05$ Mann–Whitney test.

Table 2. Correlation coefficients between intellectual coefficient (IQ), body-mass index (BMI *z*-score), social-emotional wellbeing (SEW) and 6-minute walk test (6MWT) in non-obese and obese Chilean pre-school children.

	BMI *z*-score	SEW
Entire sample ($n = 215$)		
IQ (total score)	−0.01 (0.928)	0.14 (0.040)*
6MWT (metres)	−0.18 (0.009)**	0.15 (0.036)*
Mid-low SES ($n = 48$)		
IQ (total score)	−0.31 (0.034)*	0.09 (0.570)
6MWT (metres)	−0.04 (0.799)	0.07 (0.620)
Low SES ($n = 83$)		
IQ (total score)	−0.13 (0.237)	0.12 (0.294)
6MWT (metres)	−0.12 (0.291)	0.10 (0.366)
Very-low SES ($n = 84$)		
IQ (total score)	0.17 (0.131)	0.16 (0.166)
6MWT (metres)	−0.31 (0.005)**	0.28 (0.013)*

Data shown as correlation coefficient (r) with p value (acceptance significance *$p < 0.05$ or **$p < 0.01$).

The results of correlations between IQ and 6MWT with BMI *z*-score and SEW are shown in Table 2. For the total sample a positive weak correlation of SEW with the distance walked in 6MWT and IQ was identified. Higher SEW scores were weakly but significantly associated with better physical fitness and cognitive performance. When analysed by SES category, SEW remained positively related to 6MWT and BMI *z*-score remained negatively related to 6MWT only in very-low SES. BMI *z*-score is negatively related to IQ only in the mid-low SES group.

The results of multiple linear regression analyses (MLRA) of IQ using as predictors BMI *z*-score, SEW and 6MWT in N-Ob and Ob Chilean pre-school children by SES are shown in Table 3. The MLRA for the mid-low SES revealed that the joint effect of these variables explained 13.3% of the IQ variance. For mid-low SES, β coefficients revealed that the BMI *z*-score has a negative effect on IQ; a one-unit increase in BMI *z*-score reduces IQ score by 1.8 points when controlling for the effects of age and sex.

The MLRA for low SES revealed that the joint effect of these variables did not explain any of the variability in IQ. The MLRA for very-low SES revealed that the joint effect of these variables explained 18.2% of the variability in IQ. For very-low SES, β coefficients revealed that SEW has a positive effect on IQ; a one-unit increase in SEW increased the IQ score by one point after controlling for the effects of age and

Table 3. Multiple linear regression analyses of intellectual coefficient (IQ) using as predictors body-mass index (BMI *z*-score), socio-emotional wellbeing (SEW) and physical fitness (6MWT) in non-obese and obese Chilean pre-school children by socioeconomic status (SES).

Variables and SES	R^2	β	95% CI	*p* Value
Mid-low SES ($n = 48$)	13.3			
BMI (*z*-score)		−1.81	−3.19; −0.42	0.012*
SEW (score)		0.13	−0.62; 0.88	0.727
6MWT (metres)		−0.01	−0.03; 0.02	0.792
Age (months)		−0.60	−1.11; −0.10	0.019*
Sex (girls = 0, boys = 1)		3.97	−0.34; 8.29	0.070
Low SES ($n = 83$)	0.0			
BMI (*z*-score)		−0.720	−1.85; 0.41	0.211
SEW (score)		0.41	−0.19; 1.01	0.183
6MWT (metres)		−0.01	−0.04, 0.01	0.280
Age (months)		−0.15	−0.54; 0.22	0.416
Sex (girls = 0, boys = 1)		0.59	−2.79; 3.99	0.726
Very-low SES ($n = 84$)	18.2			
BMI (*z*-score)		0.594	0.71; 1.90	0.368
SEW (score)		0.93	0.20; 1.65	0.013*
6MWT (metres)		−0.01	−0.04; 0.04	0.994
Age (months)		−0.91	−1.40; −0.42	0.001*
Sex (girls = 0, boys = 1)		3.03	−1.16; 7.22	0.153

R^2, adjusted determinant coefficient (%); CI, confidence interval; *acceptance significance $p < 0.005$ for all variables; regression model adjusted by age and sex.

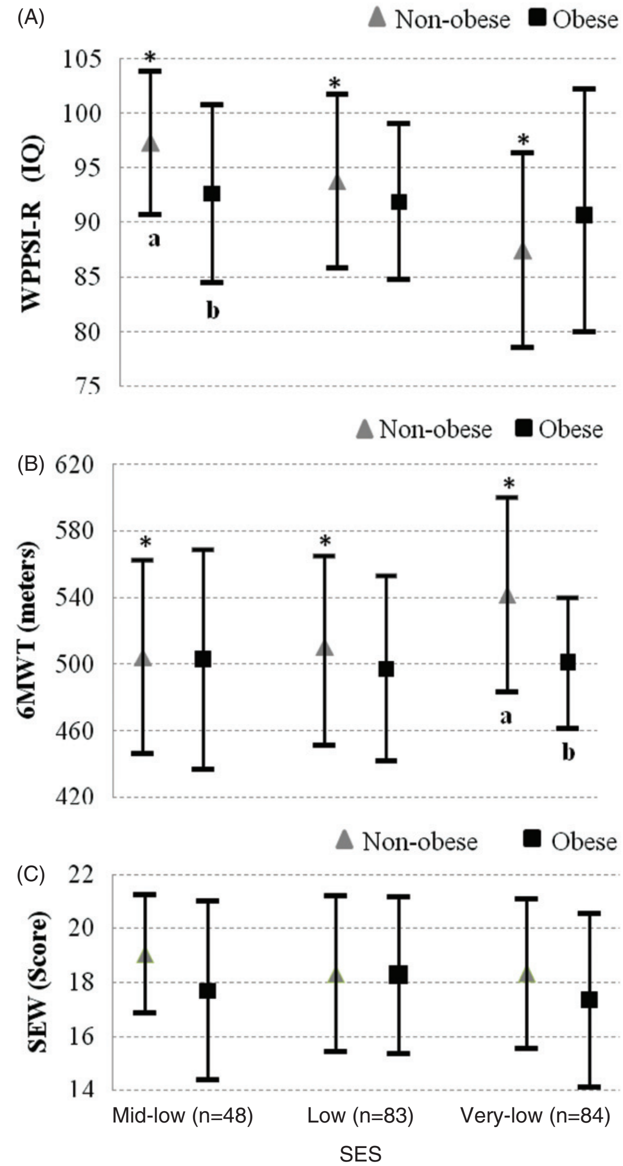

Figure 1. Mean (± SD) of intellectual coefficient (IQ), 6-minute walk test (6MWT) and socio-emotional wellbeing (SEW) by socioeconomic category (SES) in non-obese and obese children; (*a*, *b*) groups differ $p < 0.05$ Mann–Whitney test; *p for trend <0.001.

sex. Validation of MLRA revealed that the residuals had a normal distribution, showing a linear correlation between the main independent variables (SEW, 6MWT and BMI *z*-score) and the dependent variable (IQ) (data not shown).

The IQ, 6MWT and SEW by SES in non-obese and obese children are depicted graphically in Figure 1. Obese children of mid-low SES had significantly lower mean IQ scores (92.7 ± 8.1) than non-obese children (97.3 ± 6.6) ($p < 0.05$).

A positive trend was found between IQ and SES sub-category grouping in N-Ob children ($p < 0.001$, np-trend), but not in Ob children. Children of very-low SES, independent of their obesity status, presented lower IQ scores (88.9 ± 9.8) than children of low SES (92.8 ± 7.5) and mid-low SES (94.8 ± 7.7) ($p < 0.001$, Kruskal–Wallis) (data not shown). Mean 6MWT scores were significantly lower among Ob children of very-low SES (507.7 ± 39.2 m) compared to N-Ob children (541.9 ± 58.4) ($p < 0.001$). A negative trend ($p < 0.01$) was found between 6MWT scores and SES in N-Ob children. No significant differences in mean SEW scores were found between Ob and N-Ob children; no statistically significant differences between SES groups were noted.

Discussion

In this study we found a positive correlation of low magnitude between SEW and IQ in pre-school children. Several studies have shown that children's emotions affect the development of cognitive tasks (Amsterlaw et al., 2009) and that poor children can experience emotional instability due to living in less favourable conditions (Grantham-McGregor et al., 2007). These observations partly explain our results in which there was a positive effect of prevailing SEW on IQ in children of very-low SES.

This study demonstrates that there is an interaction between SES and obesity that affects the IQ of pre-school children, in contrast to results from previous studies that have shown lower performance on cognitive tests among obese children independent of their socioeconomic condition (Sorensen et al., 1983). We first observed that among N-Ob children IQ increases with improved socioeconomic status, indicating that in normal-weight children social and economic conditions are strong modulators of intellectual development. This has been demonstrated in several studies that have found SES to be an important predictor of neurocognitive performance, particularly of language and executive function (Hackman & Farah, 2009). The relevance of SES to cognitive neuroscience lies in its surprisingly strong relationship to cognitive ability, as measured by IQ and school achievement beginning in early childhood. However, in obese children the cognitive development findings were different. Obesity was negatively associated with cognitive development among pre-school children only from the mid-low SES. This indicates that, in children of better socioeconomic status, changes in intellectual development may be mediated by the fact that both parents work, which could lead to increased intake of unhealthy foods and inadequate stimulation resulting in higher obesity rates and lower intellectual development. However, we cannot assert that the condition of obesity affects brain function.

It has been shown that obesity is associated with poor cognitive function and a reduction in brain volume (Taki et al., 2008). In fact, comparisons of the cerebellar volume of patients with Prader–Willi syndrome and early-onset obesity revealed that both groups had smaller volumes than the non-obese control group. These results raise the possibility that early childhood obesity retards both cerebellar and cognitive development (Miller et al., 2009). This has also been observed in children from high-income families in industrialized countries. For example, in a study of 3- and 4-year-old German pre-school children, a one-unit increase in BMI in males represented a decrease in verbal abilities of almost one point (Ettner & Grzywacz, 2003). Another study among 6-year-old girls from Germany found a negative association between obesity and cognitive abilities (Cawley & Spiess, 2008). Whether these relationships are causally related requires further study. Although the characteristics of the present sample are different and not entirely comparable to results from industrialized countries, our findings suggest that, in a context of rapid economic development, an increase in childhood obesity may have adverse consequences on cognitive development of low-income children. In addition, SEW plays a significant role in the intellectual development of Chilean children of very-low income. These findings are relevant, considering that between 3–8 years of age children develop comprehension, thinking and problem-solving processes (Amsterlaw et al., 2009).

Our findings also indicate that obesity has a negative effect on physical fitness, as reflected by the shorter distance walked in the 6MWT and a greater rise in heart rate. The performance on 6MWT of normal-weight children of mid-low SES was lower than children of very-low SES. This suggests that household resources and appliances promote a sedentary lifestyle and higher educational level did not translate into better physical fitness levels. Similar results were found by Freitas et al. (2007) among boys from the low SES group, who performed significantly better than high SES boys in a 12-minute run.

The strengths of the study are: the sampling procedure used to select subjects from the cohort allowed us to recruit the required number of non-obese and obese children and the selection of the study sample provided the opportunity to better control the characteristics of the subjects and potential confounders. Some limitations should be noted regarding this study: the SEW, physical performance and SES data were collected only once, when the child was evaluated for IQ, and therefore all three factors may have changed in either a positive or negative direction during the course of the subjects' early life. As a result, the cross-sectional nature of our study precludes any causal inference.

In conclusion, this study provides evidence that in pre-school Chilean children from low-income families cognitive ability changed according to SES. Obesity was not only negatively associated with cognitive development, but the SEW also plays an important role. In countries with a high prevalence of childhood obesity, intervention programmes should promote a healthy diet and physical activity. Longitudinal studies are needed to document the effect of SEW on cognitive development of Chilean children.

Acknowledgements

This study was supported by grants from FONDECYT (Project 1090252), the Chilean National Board for School Assistance and Scholarships (Junta Nacional de Auxilio Escolar y Becas, or JUNAEB) and PROMEP México.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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