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Original Article

# Trends of weight gain and prevalence of overweight and obesity from birth to three years of age

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ABSTRACT

*Objective:* To examine the changes in children's weight-for-height at six monthly intervals between birth and three years old (3yo) from different counties across Chile and to determine if children had overweight or obesity, and if so, whether it was a transient or persistent change.
*Subjects and methods:* Longitudinal data were obtained from routine medical check-ups and 8,373 children were selected from nine counties in Chile through a non-randomised sample design. Weight-for-height z-scores (WHZ) were generated and categorized as wasted, normal, overweight, and obese using WHO standards. Repeated-measures ANOVA were used to analyse the changes in WHZ over the seven measurements as well as based on having normal, overweight, or obese WHZ at 3yo. The number of times having overweight or obesity was counted (from 0 to 7 times). The timing of having overweight and obesity was computed as well as all combinations of the patterns.
*Results:* Mean WHZ significantly increased up to 18 months of age and declined thereafter ($p \ll 0.001$). Overall mean WHZ was 0.743, prevalence of overweight 31.2% and prevalence of obesity 10.0%. Children categorised with overweight or obesity at 3yo showed significantly higher and sustained pattern of weight gain compared with children with normal WHZ. Once a child had overweight or obesity they tended to remain with it and did not return to a weight-for-height in the normal range.
*Conclusion:* The increasing prevalence of overweight and obesity in Chilean children is of concern. There is a need for greater healthcare promotion and prevention of this disease from infancy.
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## Introduction

Childhood obesity is the most prevalent nutritional disease in developed countries and has dramatically increased over the last three decades [1–5]. Chile is not exempt from this epidemic as it has one of the highest prevalences of childhood overweight below five years of age in Latin America and the World (9.3%) [6]. Over the last 30 years or so the nutritional status of Chilean children has changed considerably and childhood obesity has increased in six years old from 5.5% in boys and 4.8% in girls in 1987–26.0% and 21.2% in boys and 21.2%, respectively in 2013 [7,8]. Nutritional transition, characterised by substantial economic and health improvements, changes in food intake and increase in sedentary habits have been put forward as the main factors causing the rise in overweight and obesity in Chilean children [9–11].

Childhood obesity is determined by genetic, behavioural, environmental, and social factors [12]. It has been observed that higher frequencies of overweight and obesity in mid-childhood and later in life have been associated with accelerated weight gain during the first months of life [13–15], paternal and maternal obesity [16], birth weight, gestational age, parity, weight gain during pregnancy of the mother, gestational diabetes, duration of breast milk, age of giving formula-based milk, socioeconomic status, smoking during pregnancy, among others [17,18]. Additionally, the rise of weight in populations with high overweight and obesity prevalence can be traced to very early in life and it is associated with risk of obesity later in life [14,15,17–20]. Kain et al. [21] utilising a sample of Santiago children observed that the incidence of obesity (new cases of obesity within a specified period, commonly one year) develop between six and 24 months of age. Moreover, they observed that having overweight or obesity after birth increases the risk of obesity and central obesity at seven years of age. These results indicate that

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knowledge of the trends of weight gain as well as the prevalence of overweight and obesity during early childhood are important to track children at risk of having overweight or obesity in later life. However, there is a dearth of information on the trends in overweight and obesity of Chilean children from birth to three years of age from different regions and counties. Longitudinal studies of weight gain have generally selected few counties or towns from Santiago [21,22], therefore they may not represent the variation within the country. So, the aim of this study was to determine the changes in children's weight-for-height at six monthly intervals between birth and three years of age from different counties across Chile and to see if children had overweight or obesity during this period, and if so, whether it was a transient or persistent change.

## Material and methods

This was a retrospective nonrandomised longitudinal study based on Chilean infants from nine counties (Alto Hospicio, Coquimbo, Lo Prado, Quinta Normal, Talcahuano, Tirúa, Puerto Montt, Punta Arenas, and Easter Island). The present research used data collected as part of children's routine medical check-ups. Each child had their height and weight measured by trained nurses and physicians at monthly intervals up to one year of age and then at six monthly intervals until three years of age. Information was also available on mode of delivery, occupation of the parents, sex of the child, birth order, date of birth, age of the mother, age of cessation of taking breast milk, age of giving formula-based milk, and age of giving other types of food. The data used related to children born between January 2007 and January 2011 who were raised until three years of age in the same region or county of birth. In order to study the trends over time children had to have at least seven height and weight measurements, one of which was within three months of their 3rd birthday. Children were excluded if they had developmental conditions and had less than 37 weeks of gestational age. Children living in Easter Island that did not have Rapanui surnames were excluded from the sample in order to ascertain the nutritional status of more native children from Easter Island and not recent migrants from mainland Chile. As children did not have their weight and height measured at exactly six monthly intervals, third order polynomial regressions were used to generate the best fitting curves from which predicted height and weight at exactly six month intervals was calculated. The age of the child, in days, was obtained by subtracting the date of measurement from the date of birth. Data from 24,275 children were obtained from the nine selected counties. From these data, a total of 8373 children (4293 males and 4080 females) were selected for the study, after excluding individuals with insufficient and inaccurate measurements to fit the third order polynomials, missing z-scores values, outside the WHO 2006 exclusion range (<−5SD and >5SD) [23], database mismatch, pre-term infants, developmental, and genetic disorders, and non-indigenous Easter Island children (Fig. 1). Comparison between selected and excluded children showed that the former had significantly smaller WHZ at birth, 12, 18, and 24 months, whereas the effect sizes (as measured by Cohen's D) were very small (≤0.075) (table available in Supplementary material 1). It is possible that the differences between the selected and excluded samples may be due to the presence of pre-term infants in the excluded sample.

Weight-for-height z-scores (WHZ) to the nearest day, using the WHO 2006 standards [23], were calculated for each child. These scores were then used to create the weight status categories of wasting (WHZ ≤ −2 SD), normal (WHZ > −2 SD and <1 SD), overweight (WHZ ≥ 1 SD and <2 SD), and obesity (WHZ ≥ 2 SD), as used by the Chilean authorities [24,25]. The number of times a child had overweight or obesity between birth and three years of age

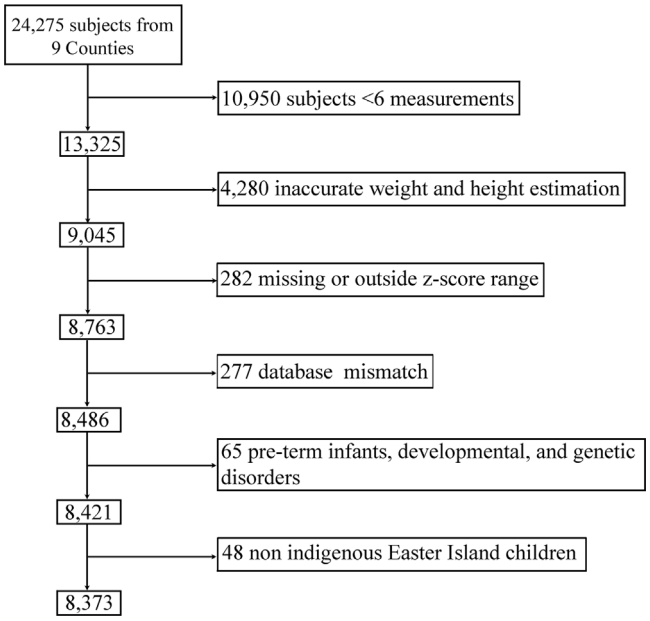


**Fig. 1.** Consort flow diagram of this study.

was counted for each individual and the range was zero (never having the condition) to seven times (having the condition at all ages) resulting in 126 combinations. In order to know the timing of having overweight or obesity and obesity only from birth to three years old, a combined classification of all the 126 combinations were computed. Repeated-measures analyses of variance (R-ANOVA) were used to analyse the changes in WHZ over the seven measurements in the whole sample as well as the weight status categories of normal, overweight and obese children with normal, overweight and obesity. The effect size of each independent variable was computed using partial eta-squared statistic calculated as the sum of squares effect over sum of squares effect plus the sum of squares error. A small effect size was defined as ∼0.01, medium effect size as ∼0.06 and large effect size as ∼0.14 following Cohen [26].

### *Ethical clearance*

Study protocols for using the data collected at the routine medical check-ups of each child were approved by ethical committees from the Iquique, Coquimbo, South Easter Santiago, Western Santiago, Talcahuano, Arauco, and Valdivia Health Services, the Alto Hospicio, Coquimbo, Quinta Normal, Talcahuano, Tirúa, Puerto Montt, and Punta Arenas Municipality Health Directors, as well as the Director of Hanga Roa Hospital, Easter Island.

## Results

Table 1 provides information on the means and standard deviations (SD) at each of seven measurements as well as the prevalences of wasting, normal, overweight, and obesity. The prevalence of wasting remained very low at each measurement ranging from 0.05% to 0.1% between birth and three years of age. The prevalences of overweight increased from 18.4% at birth to 36.7% at 18 months of age before falling to 27.5% at 30 months of age and increasing slightly to 28.1% at 36 months of age. Similarly, the prevalence of obesity increased from 3.7% at birth to 12.8% at 18 months of age and declined to 9.7% at 30 months of age, but then increased to 12.2% at 36 months of age. Chi square tests showed highly statistical associations between the weight status categories and the age intervals, and small effect sizes (Cramér's V < 0.15).

**Table 1**
Frequencies, percentages (95% CI confidence intervals of percentages), means, and standard deviations of WHZ cut-offs among age intervals (n = 8373).

| Age (months) | Wasting | Normal | Overweight | Obesity | Mean | SD |
|---|---|---|---|---|---|---|
| Birth | 83 | 6446 | 1538 | 306 | 0.249 | 0.97 |
| | 1% (0.8–1.2) | 76.9% (76.1–77.9) | 18.4% (17.5–19.2) | 3.7% (3.3–4.1) | | |
| 6 | 28 | 5087 | 2370 | 888 | 0.735 | 1.021 |
| | 0.3% (0.2-0.5) | 60.8% (59.7–61.8) | 28.3% (27.3–29-3) | 10.6% (10.0–11.3) | | |
| 12 | 6 | 4911 | 2658 | 798 | 0.814 | 0.902 |
| | 0.1% (0.0–0.2) | 58.7% (57.6–59.7) | 31.7% (30.7–32.8) | 9.5% (8.9–10.2) | | |
| 18 | 4 | 4224 | 3075 | 1070 | 0.996 | 0.894 |
| | 0.1% (0.0–0.1) | 50.4% (49.4–51.5) | 36.7% (35.7–37.8) | 12.8% (12.1–13.5) | | |
| 24 | 6 | 4507 | 2901 | 959 | 0.915 | 0.933 |
| | 0.1% (0.0–0.2) | 53.7% (52.8–54.9) | 34.7% (33.6–35.7) | 11.5% (10.8-12.2) | | |
| 30 | 23 | 5234 | 2301 | 815 | 0.702 | 1.013 |
| | 0.3% (0.2–0.4) | 62.5% (61.5–63.5) | 27.5% (26.5–28.5) | 9.7% (9.1–10.4) | | |
| 36 | 31 | 4971 | 2353 | 1018 | 0.789 | 1.079 |
| | 0.4% (0.3–0.5) | 59.3% (58.3–60.4) | 28.1% (27.1–29.1) | 12.2% (11.5–12.9) | | |

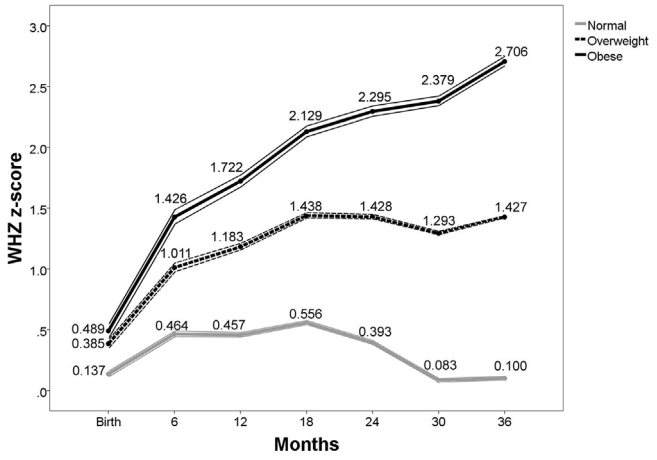


**Fig. 2.** Mean changes of WHZ from birth to 3 years of age in children with normal, overweight and obese WHZ at 3 years old.

Mean WHZ increased from +0.249 SD at birth to reach +0.995 SD at 18 months and then declined to +0.790 SD at three years of age. R-ANOVA revealed considerably within-child heterogeneity over the seven measurements ($F = 1450.43$, $p < 0.001$) and post hoc tests showed that the mean WHZ was significantly different among all age intervals, except between six and 30 months and between 12 and 36 months. Additionally, R-ANOVA showed no significant association between sex and WHZ over the seven measurements, indicating that boys and girls had a similar pattern of WHZ from birth to three years of age. However, prevalence of obesity was higher among boys at six months (boys = 17.2%, girls = 12.2%), twelve months (boys = 15.3%, girls = 12.6%), and 18 months of age (boys = 21.3%, girls = 19.0%).

Fig. 2 shows the means of WHZ between birth and three years for children who were classified as having normal ( > −2 SD and <1 SD), overweight (>1 SD and <2 SD), and obese (≥2 SD) WHZ at three years of age with the lowest mean in children with normal WHZ and the highest mean in children with obesity. One-way ANOVA and post hoc tests revealed that the WHZ means of children classified as having normal (+0.137 SD), overweight (+0.385), and obese (0.489 SD) WHZ at birth were significantly different, while the effect sizes were small (Eta-squared = 0.02). From six months of age onwards, the WHZ means showed significant differences and large effect sizes (Eta-squared: 6 months = 0.12, 12 months = 0.26, 18 months = 0.41, 24 months = 0.54, 30 months = 0.65, 36 months = 0.72). For children with obesity, the WHZ mean scores increased in a linear pattern over time, and the mean scores for children in the normal or overweight range of WHZ did not show the same pattern (Fig. 2). These trends were confirmed by R-ANOVA, which revealed that children with overweight and obesity showed statistically significant within-child heterogeneity over the seven measurements. Additionally, significant between-subjects effects indicated that the trend between birth to three years of age was not the same for children with normal, overweight and obese WHZ. Eta squared indicated a large effect size (Eta-squared = 0.52).

### *Number of times a child had overweight or obesity and obesity only*

Every child was classified by the number of times they had either overweight or obesity and obesity only at each of the seven measurements from birth to three years, with a range of one to seven (Table 2). Over the three years nearly 70.0% of the children had either overweight or obesity at least once. Approximately 13.0% of children had overweight or obesity once, 7.0% twice, 8.0% three times, 10.5% four times, 10.3% five times, 14.7% six times and 6.1% seven times between birth and three years of age. Over 25.0% of children had obesity at least once over the seven measurements while 9.0% of children had obesity once over the seven measurements. The percentage of children whose WHZ was within the obese range once was 9.2%, twice was 3.6%, four times was 3.8%, five times was 2.6%, six times was 2.2% and seven times was 0.2%. The percentage of individuals who had obesity slightly increases from twice to four times and decreased afterwards.

### *Timing of having overweight or obesity and obesity only*

All 126 different combinations of having overweight or obesity across the seven age intervals were computed. The combinations with the highest frequencies were for children who had overweight or obesity at 12 months or before and remained so thereafter (1957 children, 23.37%). A smaller percentage of children had overweight or obesity at 18 months and 24 months and remained so (650 children, 7.64%). In total, 2597 children (31.02%) had overweight or obesity from 12 months or before, indicating that once a child had overweight or obesity they tended to remain with it. A smaller percentage of children had normal WHZ after having overweight (965 children, 11.52%). Table 3 shows the number and percentage of the eight combinations of having overweight or obesity and obesity only at 12, 24, and 36 months. Children with overweight or obesity at 12 months who were within the normal range at 36 months were classified as having an 'improved' weight status. Children in the normal weight range at 12 months who were subsequently in the overweight or obese range at 36 months were classified as having a 'worsened' weight status. There was a much higher percentage of children who worsened (40.3%) than improved (17.6%).

**Table 2**
Numbers and percentages from the total sample (in italics) of the number of times of being overweight or obese and obese only.

| Type | 0 times | Once | Twice | 3 times | 4 times | 5 times | 6 times | 7 times | Total times being |
|---|---|---|---|---|---|---|---|---|---|
| Overweight or obese | 2553 | 1076 | 570 | 700 | 878 | 861 | 1228 | 507 | 5820 |
| | *30.5%* | *12.9%* | *6.8%* | *8.4%* | *10.5%* | *10.3%* | *14.7%* | *6.1%* | *69.5%* |
| Obese | 6260 | 769 | 303 | 309 | 320 | 214 | 181 | 17 | 2113 |
| | *74.6%* | *9.2%* | *3.6%* | *3.7%* | *3.8%* | *2.6%* | *2.2%* | *0.2%* | *25.3%* |

**Table 3**
Number and percentage of the combinations of being overweight or obese and obese only at 12, 24 and 36 months of age.

| Being overweight or obese at (months) | | | n | Percent | Situation |
|---|---|---|---|---|---|
| 12 | 24 | 36 | | | |
| no | no | no | 3,528 | 42.1% | no change |
| yes | no | no | 549 | 6.6% | improved* |
| no | yes | no | 254 | 3.0% | improved |
| no | no | yes | 341 | 4.1% | worsened** |
| yes | yes | no | 671 | 8.0% | improved |
| yes | no | yes | 95 | 1.1% | worsened |
| no | yes | yes | 794 | 9.5% | worsened |
| yes | yes | yes | 2,141 | 25.6% | worsened |
| **Being obese at (months)** | | | **n** | **Percent** | **Situation** |
| 12 | 24 | 36 | | | |
| no | no | no | 6,828 | 81.5% | no change |
| yes | no | no | 257 | 3.1% | improved |
| no | yes | no | 100 | 1.2% | improved |
| no | no | yes | 295 | 3.5% | worsened |
| yes | yes | no | 170 | 2.0% | improved |
| yes | no | yes | 34 | 0.4% | worsened |
| no | yes | yes | 352 | 4.2% | worsened |
| yes | yes | yes | 337 | 4.0% | worsened |

* Children with overweight or obesity at 12 months who were within the normal range at 36 months.
** Children in the normal weight range at 12 months who were subsequently in the overweight or obese range at 36 months.

All the 126 combinations of having obesity only were also computed, showing that children with obesity were 25.3% of the total sample. A total of 549 (6.6%) children had overweight or obesity until 12 months of age and returned to normal WHZ afterwards, while 794 (9.5%) children had normal WHZ until 12 months of age and had overweight or obese WHZ later. Similarly, a total of 257 (3.1%) children had obesity until 12 months of age and returned to normal WHZ afterwards, while 352 (4.2%) children had normal WHZ until 12 months of age but had obese WHZ later. Children whose weight status improved comprised 6.3% of the sample, whereas children with normal WHZ who worsened made up 12.2% of the sample (Table 3). These results show some evidence that once a child had obesity they tended to remain that condition.

## Discussion

There was little evidence in this Chilean cohort of undernutrition as the prevalence of wasting was low (the highest prevalence of wasting was 0.1% birth), but instead there was considerable evidence of overnutrition, both overweight and obesity (the average between birth and three years of age were 29% and 10%, respectively). Previous studies in Chile have established that wasting is not a significant public health nutrition issue [27]. Instead Chile is living in a nutrition transition [9] and childhood overnutrition is nowadays a matter of concern in Chilean public health [6–8]. The present study showed that at six months of age at least 10% of Chilean children had obesity increasing until three years of age. At birth 18% of newborns had overweight, with the prevalence doubling by 18 months of age. Furthermore, there was clear evidence that within-subjects WHZ varied considerably between birth and three years of age, showing a dramatic increase of WHZ means from birth to three years of age compared with the WHO 2006 standard. At 18 months of age, the WHZ mean was nearly one standard deviation above the WHO 2006 standard although falling to 0.789 SD at three years of age. Children with overweight reached the highest prevalence at 18 months of age and declined up to 36 months of age, while obesity prevalence peaked at 18 months of age and showed an oscillating pattern thereafter.

The results of this study are broadly in keeping with Kain et al. [21] who found in a sample of infants from Santiago that the weight gain between six and 24 months of age as measured by BMI z-score was higher (Girls: 0–6 months $0.5 \pm 1.0$, 6–24 months $0.9 \pm 1.0$; Boys: 0–6 months $0.5 \pm 1.1$, 6–24 months $0.9 \pm 1.0$) compared with the expected BMI gain based on the WHO 2006 standard.

The Global Nutrition Report 2016 [6] reported on the prevalences of obesity in children below five years old in different countries worldwide (126 countries). Following the results obtained of our study, Chile would be classified as 27th position of highest obesity. However, as our study only considers children from birth to three years of age, it is possible that Chile would be more highly placed worldwide in obesity rankings if a wider age range was used.

The present study also showed that the prevalence of overweight and obesity increased at 36 months of age and different trajectories of WHZ were apparent among normal, overweight, and obesity with a rebound of WHZ in children with overweight and obesity. In agreement with Kain et al. [22] the highest increase in WHZ in children with obesity was observed between birth and six months of age. However, in the current study children with obesity showed more rapid weight gain between birth and six months of age and by 18 months of age the mean z-score difference was about 0.4 SD higher. Furthermore, children with normal WHZ in the current study showed higher weight gain between birth and six months of age, while in Kain et al. [22] the highest weight gain was observed between six and 12 months of age. These results suggest different trajectories of weight gain at an early age when a geo-

graphically broader sample is considered, which would be more reflective of the urban situation across Chile.

One of the interesting findings of the study was that there were significant differences in mean birth weights between children who had normal, overweight, and obese WHZ at three years of age i.e. a child who was born with a higher WHZ tended to continue to have a higher z-score at three years of age. These results suggest that the infant with obesity may have a different metabolic reaction compared to children with normal and overweight WHZ. Schellong et al. [28] demonstrated through a systematic review and a meta-analysis involving 643,902 persons that high birth weight predisposes for later overweight. Essentially birth weight is determined by *in-utero* developmental conditions [29,30], such as the maternal-fetal food supply [31,32]. It has been observed that overweight and diabetes during pregnancy is associated with foetal overnutrition, high birth weight, fatness and macrosomia at birth [31–36]. Thus, maternal factors in pregnancy would be a cause of the elevated birth weight. Unfortunately, the current study has no information on maternal weight gain during pregnancy or maternal BMI which are known to influence birth weight.

It is observed that the increase of the mean WHZ across the age intervals is due to both children with overweight and obesity. At birth 78% of children had not overweight or obesity, which decreased almost up to 60% at three years of age, showing that an important proportion of children with overweight were born with normal birth weight. These results are in accordance with previous studies which showed that children with overweight usually had a normal birthweight i.e. they had not overweight at birth [19,22].

Analyses undertaken on the number of times a child had overweight or obesity revealed that nearly 70% of children had either overweight or obesity and 25% only obesity one or more times between birth and three years. The highest percentages of the number of times having overweight or obesity were found at six, four, and five times, indicating that once a child has overweight or obesity there is a tendency for it to remain. This finding is also supported by the analyses on the timing of having overweight or obesity. On the other hand, the number of times having obesity showed lower persistence throughout the studied age range. However, the timing of having obesity showed that there is a higher percentage of children worsened compared with those who improved. This finding suggests that once children have obesity they remain so.

The low persistence of children with obesity from birth to three years of age is because children had obesity after birth; only 3.7% of children had obesity at birth, increasing to 10.6% at six months. A similar increase was observed in children with overweight. This study suggests that early infancy may be critical period for development and persistence of overweight and obesity.

## Conclusion

This study shows that Chilean children attending the public health system have a high prevalence of overweight and obesity during their three first years of life, even higher than what has been reported in previous studies. The increasing prevalence of overweight and obesity from six months of age is of considerable concern. It was also observed that children that had overweight or obesity at three years of age had higher WHZ means at birth compared with children with normal WHZ at three years of age. There is a need for greater health promotion activities to tackle the problem of childhood overweight and obesity since early infancy. It is important to count on maternal nutritional status and data of metabolic patterns of children in order to understand whether high prevalence of obesity is due to consumption of excess food or a change in the metabolic imprinting in the infant population with obesity.

Further analyses are required in order to understand the effect of socio-demographic and regional factors on variation of weight-for-height in Chilean children.

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## Statement of conflicts of interest

None.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.orcp.2018.10.005.

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