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Does maternal grandmother's support improve maternal and child nutritional health outcomes? Evidence from Merida, Yucatan, Mexico

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Abstract

In humans, high levels of investment are required to raise offspring, because of the prolonged developmental period and short interbirth intervals. The costs borne by individual mothers may be mitigated by obtaining social support from others. This strategy could be particularly valuable for first-time mothers, who lack first-hand experience and whose offspring have higher mortality risk than later-born siblings. As raising children is potentially stressful, mothers may gain from others sharing their experience, providing knowledge/information and emotional support. Being genetically related to both mother and grandchild, maternal grandmothers may be especially well placed to provide such support, whilst also gaining fitness benefits. We tested the over-arching hypothesis that first-time mothers and their young children supported by the maternal grandmother would have lower levels of stress and better health outcomes, compared to mother-infant dyads lacking such grandmaternal support. A cohort of 90 mother-infant dyads (52 with grandmaternal support, 38 without) was recruited in Merida, Mexico. We assessed anthropometry and body composition in both mother and child, along with maternally perceived stress and child temperament, and documented maternal social relationships. No differences were found in perceived stress/temperament or anthropometry of either mothers or children, according to the presence/absence of grandmaternal support. However, a composite score of whether grandmothers provided advice on infant feeding was positively associated with child nutritional status. Mothers without grandmaternal support reported seeking more informational and emotional support from other female relatives for childcare, potentially compensating for limited/absent grandmaternal support. Our findings may help develop interventions to improve maternal and child health by targeting the dynamics of maternal social networks.

Keywords: Social capital, childcare support, maternal grandmothers, stress, mother-infant health, body composition

1. Introduction

Compared to other primates, humans must provide high levels of investment to raise their offspring, for several reasons. Human infants have high energy requirements per kg weight due to their large brain and require care over a lengthy period, yet humans also demonstrate relatively short birth intervals, which underpin the fundamental colonising tendency of our species (1,2). The composite

challenge of funding reproduction is in part solved by high levels of 'alloparenting', whereby others help mothers meet the costs of rearing individual offspring (3,4). Alloparenting is observed in other primate species, but the levels demonstrated in human societies are much greater (3,4).

While alloparenting is widely understood to help human mothers care for multiple offspring of different ages simultaneously (4)(Page et al this issue), the concept has received less consideration in the context of first-time mothers, for whom the challenges of parenting may be rather different. Rearing children is not instinctive (5), and first-time mothers may find it stressful due to the need to develop maternal skills, and their responsibility for the baby's well-being as well as themselves (6–9). In challenging environments, their lack of confidence and inexperience may contribute to higher levels of infant mortality, compared to mothers of higher parity (10). Moreover, difficulties rearing the first child may undermine the capacity to invest in future offspring, or delay the birth of the second child (11,12).

Potentially, alloparental support may be obtained from different sources (3,13). Like other social mammals, humans are capable of establishing and maintaining bonds with diverse members of their social group. Social networks provide access not only to economic support, but also practical and emotional support, companionship, protection and informational support (14). Intimate and regular contact with relatives, neighbours, and friends may therefore enhance maternal competence (15,16), which may be of particular value when the offspring are young and vulnerable (3). For instance, the presence, preferences, attitudes and practices of the maternal and/or paternal grandmother could be associated (positively or negatively) with maternal breastfeeding patterns and duration (17–19) and could influence the mother's acquisition of knowledge about breastfeeding, potentially benefitting children's survival and long-term health.

According to kinship theory (20), maternal relatives are expected to be particularly reliable sources of alloparental support, as they are genetically related to some degree with both mother and offspring, and therefore from an evolutionary perspective have a vested interest in the wellbeing of both parties.

For first-time mothers, the maternal grandmother may be a key alloparent. First, like full-sisters of the mother (aunts), maternal grandmothers share 50% of their genes with the mother, and 25% with each grandchild, independent of paternity uncertainty. Both aunts and grandmothers can therefore gain indirect fitness benefits from allomothering, however whereas sisters may compete for resources (21), after a certain age grandmothers stop producing children, and can increase their own fitness only by investing in their kin (22). Second, grandmothers have extensive knowledge and experience of the

maternal role, and due to family bonds may be an ideal source of informational, instrumental and emotional support for inexperienced mothers. In low-income settings with high mortality risk, the presence of maternal grandmothers has been associated with both improved survival and better nutritional status of grandchildren (23–25) and maternal fertility (26), though not all studies found benefits for child health (27–30). More generally, grandmothers may provide advice on infant feeding practices (31,32), and may be an important source of emotional and practical support (11,33). A study of Himba pastoralists in Namibia reported that grandmothers provided each of informational, emotional, and practical support to new mothers during the perinatal period, benefitting the nutritional status of both mother and offspring (11).

The underlying pathways through which alloparenting may benefit maternal and children health outcomes require elucidation. According to life history theory (34), every organism must allocate its resources (usually simplified to energy) in competition between competing biological functions. Originally, three primary functions were differentiated, termed 'maintenance', 'growth', and 'reproduction' (35), however, allocating resources to 'defence' (activating immune function to combat pathogens, or the stress response to address social threats) is now understood to be detrimental to the other functions (36). According to this framework, maternal investment is inherently subject to trade-offs, depending on the demand for energy from other functions. We therefore expect stress to be fundamental in the pathway between alloparental investment and child outcomes, but this pathway also has implications for maternal outcomes as stress mediates trade-offs between maternal 'maintenance' and 'defence'. For example, activating the stress response is metabolically costly (37), hence reducing maternal stress levels is predicted to increase the energy available via lactation for infant growth, as recently demonstrated experimentally (38). Similarly, stress and irritability in the infant may promote energy allocation to defence (adipose tissue, which funds immune function) at the cost of linear growth.

A life history framework provides an informative/useful way to consider the potential benefits of alloparental support from grandmothers, taking into consideration both maternal and child outcomes. Grandmothers may provide material resources directly to the mother, contribute time to childcare, or provide informational support on maternal and child nutrition. In addition, grandmothers may potentially relieve the negative effects of stress (39,40), while also helping the mother respond appropriately to infant behaviour associated with distress, such as crying (41–43). By reducing the allocation of energy to stress in both mother and offspring, the grandmother could promote better nutritional status in both parties, as well as promoting linear growth in the offspring.

We tested the over-arching hypothesis that first-time mothers and their young children with maternal grandmaternal support would have lower levels of stress and more favourable nutritional health

characteristics, compared to those lacking grandmaternal support. To test this, two groups of mother-infant dyads, with or without grandmaternal support, were recruited in Merida, Yucatan, Mexico. Although little research on grandmothers' support has been conducted in Mexico, studies suggest that maternal grandmothers are considered the most reliable and desirable helpers in this setting (44,45). We studied children ~2 years of age, as this represents a critical period for fat gain (46,47), while in terms of temperament such children can show difficult behaviours such as irritability and crying that might be associated with their health profile (48). For example, it has been suggested that infants perceived as difficult are fed more to quieten them, which could be related to subsequent fatness (41,49). Finally, we also took into account other social relationships, in order to address more comprehensively the mother's social network representing maternal social capital (50). Our approach is intended to help develop interventions to improve maternal and child health by targeting the dynamics of maternal social networks.

2. Methods

The study was conducted in Merida, the capital city (~895,000 inhabitants) of Yucatan. Merida is a regional hub and a major tourist destination, with good quality services and infrastructure relative to the broader region. Approximately 48.3% of the population are indigenous, mostly of Mayan ethnicity, however, none of the participant women in our study had characteristics that could identify them as a contemporary Maya group (e.g., presence of Mayan surnames). Nationally, Yucatan has low unemployment, and it is typical for women to work. The average daily income is Mex$141.70 (6.81 USD). According to the last census (2010), 80% reported being Catholic, the remaining 20% following other Christian religions.

Regarding the broader context, in Merida, families have been characterized by a great sense of familiarity and high levels of cohesion (51), with 28.6% of households comprising extended families that include grandparents (maternal and/or paternal) (52).The contribution to childcare by different members of the family, particularly grandmothers, has been reported in various studies in Yucatan (45,53,54).

Study design

Given the known predominance of grandmother support in Mexico (44), we designed our study to compare two groups of participants, with either high (GM+) or low (GM-) levels of support from the maternal grandmother. To decide how to allocate participants in the main study to these groups, we

conducted pilot work with a separate sample of 50 mothers with children close to the target age. These mothers completed a customized questionnaire including open-ended questions to assess the frequency and regularity of maternal grandmaternal support. The specific duration of childcare was not examined, instead we focused on the time the grandmother spent with the mother-child dyad (days per week, hours per day) to obtain a composite measure of support.

We categorised these pilot data into (a) *women without support*, where the grandmother had either passed away (n=4) or was living in another city (n=12), or b) *women with support* among whom the grandmother was either co-resident (n=6) or not (n=28). The 34 women receiving support had a median of 2 days per week of grandmaternal support. Among those receiving above this median (≥ 2 days of support), the median daily duration was 3.1 hours. Based on these pilot data, for the main study we defined mothers as GM+ if they received childcare support and had physical contact with their mothers at least twice weekly for ≥3 hrs per day, and the remaining mothers as GM- (**Figure S1**).

We then recruited a cross-sectional sample of urban mothers into the main study from different childcare centres in Merida, or through other networks such as local universities, health centres and social media (**Figure S1**). All women were the biological mothers, married or living with the child's biological father, not pregnant at the time of the study, and without diagnosis of diabetes or high blood pressure during pregnancy/delivery, and depression and/or anxiety. All women were also the biological child of the maternal grandmother.

We used a group comparison study design, powered to detected differences between groups in child growth of ≥0.66 standard deviations with 80% power, $p<0.05$, requiring at least 32 mother-child dyads per group. We invited 205 mothers to participate; 49 did not attend the recruitment sessions, 30 were ineligible, and 36 declined to participate. The final sample comprised 52 GM+ and 38 GM- women. Women allocated to the GM+ reported between 2 to 7 days per week and 3 to 10 hours per day of grandmaternal support, whereas unexpectedly, all women allocated to the GM- group reported zero days per week of grandmaternal support (**Figure S1**). Data was collected from June 2017 to July 2018, using at least two home visits.

Data collection

Using customized questionnaires (**see SI**), we obtained information on the family's current socioeconomic condition (years of education of mother and partner; household condition such as construction quality and access to basic services), sources of social support and children birth characteristics, such as birth weight.

Beyond investigating grandmaternal support itself, a key aim of the study was to ascertain if GM- mothers received greater support from other sources, such as other relatives or friends. To explore the frequent sources of support that women turn to when in need, we therefore read all participants a series of hypothetical situations or problems they might face and asked from which people and/or groups they would ask for advice and emotional support, to solve those problems. We also asked women the number of relatives and friends with whom they maintained regular contact at least once a month, and had a close relationship (i.e., with whom they felt comfortable and could talk about problems or personal matters), in order to quantify maternal social capital (50). Moreover, we asked women if they were receiving support from other social groups (yes/no responses), such as labour unions, religious and artistic associations or neighbourhood groups in their community. For GM+ mothers, we obtained data on whether the grandmother provided three specific types of childcare (yes/no responses): a) minding the child, b) taking the child to the doctor, and c) feeding the child, but we did not assess the duration of these behaviours. All questions in the questionnaires were based on literature review and long-term experience of the research team within Merida.

Despite not having physical contact and support from the grandmothers, GM- women could potentially communicate with them remotely (except where the grandmother was deceased, n=5) to ask for advice. Therefore, we collected information from all mothers on whether the grandmother had provided advice about: a) the duration of exclusive and total breastfeeding, b) ideal pregnancy weight gain, c) age for initiating complementary feeding, and d) which foods should be used for this purpose.

To measure women's overall appraisal of the stressfulness of their lives, we used the Perceived Stress Scale (PSS). This scale is a self-report instrument, comprising 14 items for measuring the perception of stress on a scale of five, from zero (never) to four (very often). Total scores for PSS-14 range from 0 to 56, with a higher score indicating greater stress (55). To assess child temperament, mothers completed the Early Childhood Behaviour Questionnaire (ECBQ) (56). This instrument comprises 201 items that assess 18 domains of temperament assessing three dimensions: Surgency (a personality trait marked by good mood and sociability), Negative Affectivity and Regulatory Capacity/Effortful Control. Scale scores are calculated as the average of ratings for all completed items, with high scale scores corresponding to high levels of the temperament dimension. The ECQB allowed us to explore if, according to their mothers, children frequently showed behaviours related to distress (Negative Affectivity). Both questionnaires have been validated in Mexican samples (57,58).

To assess maternal and child nutritional status and child growth, anthropometric measurements were taken on the left-hand side, with participants wearing light clothing. All children's measurements, and skinfolds in both mothers and children, were measured by one researcher. Other maternal measurements (weight, height, sitting height, and waist and hip circumferences) were measured by

two researchers. Technical Error of Measurement (TEM) was assessed and both intra- and inter-evaluator TEM was <1%. Weight was measured with 0.05 kg precision (Seca® scale). Height was measured in women using a moveable Martin type anthropometer, and length in children using a Rollameter100. Body mass index (BMI) was calculated. Waist and hip circumferences were measured with the subject standing, using a non-stretchable fiberglass tape (Seca®). Skinfolds were measured in children using Holtain callipers, and in mothers with Harpenden callipers. All measurements were taken following the guidelines of Lohman *et al.* (59). Stunting and overweight of both mother and child were assessed using 2006 WHO Growth Standards (60). For adult women, we assumed that height remained constant after age 19 years. For children, 'risk for overweight' and 'overweight' were categorised when children were >+1 and >+2 z-scores for weight-for-length (WLZ) respectively.

Body composition, assessed as the amount and distribution of body fat and the amount of lean mass, is an important health outcome in both children and adults (61). For instance, lean mass promotes physical and cognitive function in children (62,63) while fat promotes immune function in all age groups and provides energy for lactation in mothers (64,65). However, higher levels of fat are adversely associated with child mental health (66), and increase cardiometabolic risk in adults (67,68). In women, bioelectrical impedance was obtained and fat mass (kg) and fat-free mass (kg) was calculated using equations for Mexican adults (69), and adjusted for height to give fat free mass index (FFMI) and fat mass index (FMI). For children, subscapular skinfold was expressed as z-scores using the WHO reference. A proxy for child lean mass was calculated by obtaining standardised residuals of the regression of BMI on subscapular skinfold, expressed as z-scores, where a high z-score indicated high lean mass (70).

Statistical analyses

We used central tendency descriptive statistics, measures of variability, and frequencies/percentages to describe characteristics of the overall sample. Our main analyses compared the two groups, using Chi-Square tests, T-tests and Wilcoxon rank sum tests as appropriate to assess differences in maternal social support and in maternal and children outcomes. For the GM+ mothers only, we also describe the types of childcare provided.

In secondary analysis, we explored whether grandmaternal advice (yes/no responses) over infant feeding and pregnancy weight gain in the whole sample was associated with maternal and child nutritional status and child growth outcomes. To implement this, we used Principal component analysis (PCA), which produced a construct for grandmaternal support relating to feeding advice (type of food for complementary feeding, duration of total and exclusive breastfeeding) (**Table S1**). Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the Bartlett test of sphericity were used to confirm that PCA was appropriate. Using linear regression, we then tested associations of this PCA

construct with maternal fat mass index and child nutritional outcomes, adjusting for maternal education, height and age, and child birth weight. All statistical analyses were performed with Stata/IC 15.1 for Windows statistics package (StataCorp LP, 2017), using a significance threshold p=0.05.

3. Results

Characteristics of the sample

Of the 90 families studied, 78% were nuclear families residing separately from both the husband's and wife's natal households, while the remainder were extended families, in which at least one other paternal and/or maternal family member shared the home. In 14 of the 25 extended families the maternal grandmother was co-resident, whereas in none was the paternal grandmother co-resident. Regarding their origin, 89% of the women were born and raised in Merida. The remainder were born in another Mexican state and had moved with their family (parents and siblings) to Merida, on average (± SD) 24 ± 8 years previously.

Among the whole sample, mean (± SD) maternal height was 155.8 ± 6.0 cm, with 17% categorized as having short stature. Average maternal BMI was 27.1 ± 6.1 kg/m^2, with 53% categorized as being overweight or obese. Only 8% of the children had birth weight <2.5kg, and the frequency did not differ among the groups (p=0.980). Only 9% of the children met the criteria for stunting, while 22.5% were categorized as at risk of overweight, and 4.5% with overweight, again with no differences between the groups (p=0.350).

Regarding their background characteristics, the two groups did not differ significantly in their current age, age at pregnancy or education, their child's age or birth weight, or their partners' education, with all differences being of relatively trivial magnitude (**Table 1**). In both groups, all women had access to potable water, toilet, electricity and gas, and the housing was of durable materials. None of the women were beneficiaries of social programs such as *Becas para el Bienestar* or *Liconsa*.

INSERT TABLE 1

In terms of social capital, overall, the women reported maintaining regular contact with many relatives (Median=5, IQR 4-9) and friends (Median=4, IQR 3-8). However, regarding close relationships with those they could trust, the women reported lower numbers of friends (Median=2, IQR 1-4) and relatives (Median=3, IQR 2-5). In 66% of cases, the mother was the relative they felt closest to.

The sample is well-matched by socioeconomic conditions and social capital characteristics. These similarities helped us to verify if the differences found among the groups were related to the grandmother's support.

Comparison of outcomes between the grandmaternal support groups

Maternal social capital

When comparing the groups, the number of relatives with whom they had regular contact (GM+ Median=5, IQR 4-9 vs GM- Median=6, IQR 4-10, p=0.780) and a close relationship (GM+ Median=3, IQR 2-4 vs GM- Median=3, IQR 2-5, p=0.450) did not differ significantly (**Table S2**). GM+ women were more likely to report being closest to their mother than GM- women (79% vs 50%, p=0.004) and were significantly more likely to talk with their mother about personal issues (94% vs 63%, p<0.001), which was expected considering the criteria of the study. However, those from the GM- group were more likely to report being closest to another female relative (50% vs 21%, p=0.004). This closest female relative included aunts (n=3), cousins (n=1), nieces (n=1), sisters (n=11), mothers-in-law (n=1) and stepmothers (n=2) (**Table S3**).

The two groups showed similar distributions regarding the number of friends with whom the mothers kept in regular communication (GM+ vs Median=4.5, IQR= 3-8 vs GM- Median=4, IQR 3-10, p=0.510) and had a close relationship (GM+ Median=2, IQR 1-4 vs GM- Median=3, IQR 1-4, p=0.890) (**Table S2**). Overall, women from both groups reported being not active members of other social groups in their communities as well as not receiving support from these networks.

Finally, when prompted with hypothetical situations, women responded overall that they would seek advice and emotional support primarily from relatives, however statistical differences were still found between the groups. In particular, GM+ relied more on their mothers when needing childcare advice, whereas GM- were more likely to seek frequent support from other female relatives (p<0.001, respectively) (**Table 2**). Compared to GM+ mothers, GM- mothers also sought advice and support more from their partner and/or other relatives for financial (p=0.073), work (p<0.001) and personal issues (p=0.067) and help in the home (p<0.001).

INSERT TABLE 2

Grandmaternal advice and childcare support

In the GM+ group only, who reported whether 3 types of childcare were provided, we found that all maternal grandmothers minded the child, while 88.5% fed the child, and 38.5% took them to a doctor if necessary.

Comparing the two groups, GM+ mothers were significantly more likely to have received advice from the grandmother during pregnancy/infancy on exclusive breast-feeding duration (60% vs 37%, p=0.033) and the type of first complementary food (81% vs 47%, p=0.001), with a similar trend (p=0.082) for ideal weight gain in pregnancy, but there was no difference regarding advice on breast-feeding duration or the optimum age for introducing complementary foods (**Table 3**).

Maternal and child anthropometry and body composition

Table 3 describes comparisons of maternal and child anthropometry and body composition. No significant group differences were found in maternal weight, BMI, waist and hip circumferences or skinfolds, or in children's anthropometric outcomes. Moreover, no statistically significant differences were found between groups in maternal fat mass index (Δ=0.10 kg/m^2, 95%CI -0.5, 0.7) and fat free mass index (Δ=0.43 kg/m^2, 95%CI -0.1, 0.9), or the child's z-scores for subscapular skinfold (Δ= 0.10 mm, 95%CI -0.5, 0.7) and lean mass residual (Δ= 0.28, 95%CI -0.6, 0.04) (**Figure 1**).

Maternal stress perception and child temperament

Only 80 mothers filled the PSS and ECBQ. No significant group differences were found in the mother's stress perception (**Table 3**). Overall, the median response in the whole sample comprised being stressed 'every now and then', with the median score of 22.5 suggesting moderate stress levels in the sample (55). Moreover, no group differences were found in any of the evaluated components of child temperament by ECBQ. Overall, according to the mothers, children showed a high frequency of temperament behaviours related to extraversion and regulatory capacity over the previous two weeks.

INSERT TABLE 3, FIGURE 1

Continuous analyses of grandmaternal advice and nutrition outcomes

Supplementary **Table S4** reports results of the regression of child anthropometry and body composition and maternal FMI on the PCA score. The PCA score for feeding advice was positively associated with child WLZ (adjusted B = 0.219, 95%CI 0.028, 0.410, p=0.025), but no other associations were apparent for maternal fat mass index or child anthropometric outcomes.

4. Discussion

In our study, we assessed the associations of grandmaternal support with markers of stress and nutritional status among first-time mothers and their young children. Our main focus was on support provided when the child was aged 2 years, indexed by the grandmother spending substantial time with the family every week. A secondary aim was to investigate whether informational support from the grandmother, relating to maternal and infant nutrition in earlier periods, was associated with current nutritional outcomes in the mother or child. To our knowledge, this is the first study conducted in south Mexico that was designed to test these hypotheses. In the whole sample, we found a positive

association of grandmothers providing informational support during pregnancy/infancy with one measured of child nutritional, WLZ, status at 2 years. Despite this, we did not find that mothers receiving support in the home from the maternal grandmother differed significantly in their perceived stress, child temperament, or maternal or child nutritional status, compared to those not receiving such support.

Previous research on the contribution of grandmothers to child health outcomes has been inconsistent. It is widely understood that grandmothers tend to be influential in this context (71–73), but studies differ as to whether they improve or worsen children's outcomes. Several studies have associated grandmaternal advice with healthier feeding practices (9,74), while others have found negative effects (28), or that the effect depends on the adequacy of grandmaternal knowledge (31). Likewise, some studies have associated grandmother support with better child growth and weight gain (25,75), whereas others have found adverse associations (29,30), and the associations may also vary by age of the child (76). A range of factors are likely to contribute to this inconsistency (77). We speculate that in settings characterised by relative cultural stability regarding breast-feeding, grandmothers may provide a reliable source of knowledge based on their own experience, whereas in environments characterised by cultural change, grandmothers may provide inappropriate knowledge and impede the transition to practices that promote health.

First-time mothers are particularly in need of guidance and support, and this may help explain why, in our study, informational support relating to maternal and infant nutrition was associated with better nutritional status of the child. Our largely null findings regarding the comparison of the two groups may seem to contrast with this association but may be due to mothers in the GM- group finding additional sources of social support to compensate for the total absence of direct grandmaternal support. Such variability in the sources of support has been identified in previous research (13,21,78), and demonstrates that mothers can be flexible in finding support with childcare, depending on their circumstances. Among the Aka, for example, social networks proved able to buffer children's nutritional status when the grandmother was deceased or absent (78). Importantly, the GM- mothers in our study primarily sought closeness and support from other female relatives rather than friends, suggesting a preference to seek support from those most familiar to them. At a proximate level, this highlights the security implicit in family relationships, but at an ultimate level, it also suggests that mothers may seek support from those with an inherent vested interest in the welfare of both mother and child, as predicted by kin selection theory (20).

Our findings are consistent with other studies reporting that, in the absence of grandmothers, other female relatives can assume a maternal role (79,80). For example, the presence of aunts has been associated with increased infant survival (81), while maternal kin may benefit child growth (82).

However, a study in Malawi found greater child mortality rates when maternal grandmothers and maternal aunts were present, indicating that these associations vary by context and depend on the availability of resources, which may be subject to intra-family competition (83). Of relevance here, the behaviour of the child may also vary according to who is providing care (84,85). In our study, children without frequent contact with their grandmothers did not differ in their behaviour compared to those with grandmaternal support, which could suggest positive interactions with other female family members. In future studies, it would be valuable to obtain detailed information about the advice-giving and emotionally-supporting role of these other female relatives.

Previous studies of grandmaternal support have focused on potential benefits for the child and have rarely addressed maternal outcomes, aside from fertility (26). We hypothesised that grandmothers might reduce the mother's exposure to stress, or subsidise the energy demands of childcare. In turn, this might have implications for the mother's future reproduction, for example by making it easier for the mother to have additional children (12), or allowing energy stores to be accumulated for future lactation (86). Reducing stress has been shown experimentally to benefit both mothers and children (38), and our null findings for this maternal outcome again suggest that the GM- mothers may have resolved stress by drawing on other sources of emotional support.

Finally, other characteristics of the Yucatecan population may have contributed to the lack of differences between the groups. Our study was undertaken in an ecological context very different from most of those where positive and significant effects have previously been reported (25,82). Contemporary Yucatecan children are experiencing less infectious diseases than in previous decades, and there is also evidence that this population is experiencing the 'double burden of malnutrition' (87). It may be harder to detect associations of grandmaternal support with the nutritional status of women and children in a population experiencing both under- and over-nutrition.

From an evolutionary perspective, the longevity in humans that enables grandmothering has been suggested to have evolved precisely because of the fitness benefits of helping daughters invest in grandchildren, with whom the grandmother is genetically related (22). Our negative findings do not challenge this hypothesis. First, we found that grandmaternal advice did benefit child nutritional status, and second, natural selection could have favoured prolonged female longevity in our species regardless of whether every individual woman became an actively supportive grandmother.

Among the study limitations, our study was observational and cross-sectional, though we also obtained some information about nutritional advice retrospectively. To demonstrate a causal effect of grandmaternal support on maternal and child outcomes, an experimental approach would be required, which is clearly unethical. However, our approach of comparing two groups is quasi-experimental,

since as intended, the background characteristics of the two groups were very similar, while our study design also inherently controlled for parity, and we excluded women with certain health conditions. Although our treatment of grandmother support as a binary variable leads to information loss, we consider it as a strength of the study by reducing the possibility of confounding by other factors. In turn, this increases confidence in our interpretation that the greater support obtained by mothers from other female relatives was causally associated with the lack of grandmaternal support. Future studies could address this further through qualitative work, explicitly asking if mothers seek support from others because grandmaternal support is lacking. Among other limitations, we could not carry out in-depth interviews to explore the quality of the women's social relationships. Despite this, our data addressed positive aspects of relationships, such as emotional support (88).

5. Conclusion

Our study found that while grandmaternal advice on nutrition in early life was associated with improvements to children's nutritional status, direct support of grandmothers to mothers of two-year old children was not associated with differences in maternal stress, child temperament or maternal and child nutritional status, compared to mothers lacking such support. We suggest that these null results may be due to the fact that when grandmothers were not available, mothers drew on others, typically female relatives, for emotional support and advice. These findings underline the flexibility in human social support networks, indicating that when key sources of support are not available, women may turn to others to ensure they get the supported required to raise invest in and nurture their children.

Ethics

Ethical permission was obtained from the University College London Ethics Committee and by the Bioethics Committee for the Study of Human Beings in Mexico. All participants gave written informed consent for themselves and their children.

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Authors' contributions

AVV, JW, MF and FD assisted in development of protocols and methods implementation of the study. AVV, HCG and CBM conducted data collection. AVV conducted data analysis. AVV and JW drafted the manuscript which was reviewed and approved by all authors. We declare no competing interests.

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Table 1. Background characteristics [mean (SD) or median (IQR)] of the two groups of mothers with (GM+) or without (GM-) grandmaternal support

	GM+ (n=52)	GM- (n=38)	Difference
Mothers			
Age (years)	29.4 (4.6)	30.3 (6.1)	-0.8 (-3.1, 1.4)[A]
Age at pregnancy (years)	27.0 (4.8)	27.9 (6.2)	0.9 (-1.4, 3.2)[A]
Education (years)	16.0 (1.0)	16.8 (3.0)	-0.0 (-0.3, 0.2)[B]
Children			
Age (years)	1.95 (0.35)	1.84 (0.23)	-0.10 (-0.35, 0.14)[B]
Birth weight (kg)[†]	3.03 (0.42)	3.15 (0.51)	-0.12 (-0.31, 0.08)[A]
Partners			
Education (years)	16.0 (5.0)	16.0 (5.0)	-0.1 (-0.4, 0.1)[B]

[A] T-test: Difference (95%CI) between means.
[B] Mann-Whitney: Difference between medians (95%CI).
[†] From birth certificates.

Table 2. Comparison of sources from whom mothers sought support between groups with (GM+) and without (GM-) grandmaternal support [a]

	GM+ (n=52)				GM- (n=38)			
Who do you go to when you need advice and support about…? (%)	GM	Partner	Female relatives	Females friends	GM	Partner	Female relatives	Females friends
Childcare*	90	0	10	0	47	0	53	0
Work problems*	37	54	9	0	3	86	11	0
Help at home (such as household chores and childcare)*	65	23	12	0	24	26	50	0
Financial issues**	45	38	17	0	21	55	24	0
Disagreements with the partner**	50	0	21	29	26	0	37	37
Personal issues with a relative/friend/work colleague***	27	56	17	0	8	66	26	0

[a] The table shows the sources of support for the two groups of mothers and the proportion of women that use each source when they needed help/advice and emotional support regarding different topics and situations. The sources of support are those reported by the mothers. Overall, women invested primarily in family relationships.

GM = maternal grandmother.

*p<0.001
**p=0.073
***p=0.067

P-values refer to differences between groups analysed using Chi-square, but in one case (work problems), Chi-Square assumptions were not met, and the p-value of the Fisher's exact test is reported.

Table 3. Comparison of anthropometric outcomes, maternal stress, child temperament [mean (SD) or median (IQR)] and frequency of grandmaternal advice (%) between groups with (GM+) and without (GM-) grandmaternal support

Anthropometry	GM+ (n=52)	GM- (n=38)	Difference and 95%CI
Women (n=90)			
Weight (kg)	62.3 (17.1)	60.9 (9.0)	0.0 (-0.3, 0.2)[B]
Height (cm)	155.3 (5.8)	156.4 (6.4)	-1.0 (-3.6,1.5)[A]
BMI	27.3 (7.7)	24.6 (4.9)	-0.1 (-0.3, 0.2)[B]
Waist circumference (cm)	88.2 (18.0)	86.3 (14.5)	-0.0 (-0.3, 0.2) [B]
Hip circumference (cm)	102.2 (12.8)	100.6 (8.7)	-0.1 (-0.3, 0.2)[B]
Subscapular skinfold (mm)[#]	19.8(9.9)	19.4 (7.8)	0.0 (-0.2, 0.34)[B]
Children (n=89)[†]			
Length-for-age (z-score)	-0.24 (0.95)	-0.31 (1.23)	-0.07 (-0.39, 0.53)[A]
Weight-for-length (z-score)	0.59 (0.98)	0.28 (0.96)	0.31 (-0.10, 0.73)[A]
Stress perception and infant's temperament[§]	GM+ (n=45)	GM- (n=35)	Difference and 95%CI
Women (n=80)			
PSS (total score)	22.0 (7.0)	23.0 (12.0)	-0.10 (-0.16, 0.37)[B]
Helplessness	14.0 (6.0)	15.0 (8.0)	0.11 (-0.15, 0.38)[B]
Self-efficacy	8.0 (4.0)	9.0 (5.0)	-0.05 (-0.21, 0.32)[B]
Children (n=80)			
Negative affectivity	2.83 (0.40)	2.91 (0.42)	0.12 (-0.13, 0.38)[B]
Surgency/Extraversion	3.18 (0.49)	3.37 (0.31)	0.23 (-0.03, 0.48)[B]
Regulatory capacity	3.26 (0.41)	3.17 (0.38)	-0.01 (-0.27, 0.25)[B]
Proportion of women receiving advice from grandmother (%)[c]	GM+ (n=52)	GM- (n=38)	p-value for χ^2 test
Duration of EBF	59.6	36.8	p = 0.03
Duration of total BF	48.1	39.5	p = 0.42
Ideal weight gain during pregnancy	44.2	26.3	p = 0.08
Child age to initiate CF	48.1	39.5	p = 0.41
First food to initiate CF	80.8	47.4	p = 0.001

SD: Standard deviation; IQR: Interquartile range; BMI: Body mass index; EBF: Exclusive breastfeeding; BF: Breastfeeding; CF: Complementary feeding.
[A] T-test: Difference (CI 95%).
[B] Mann-Whitney: Difference between the medians (CI 95%).
[c] Chi-squared test (χ^2 test) for grandmaternal advice.
[#]Only 84 mothers were measured (GM+=47 and GM-=37) due to difficulty finding the landmark to measure.
[†] One missing infant data from the 'GM- group'. The mother withdrew from the study before obtaining the child's measurements.
[§]Only 80 mothers completed the PSS and ECBQ. Ten mothers withdrew from some aspects of the study.

Figure 1. Comparison of maternal and child body composition between groups with and without grandmaternal support. (a) Maternal fat mass index, b) Maternal fat free mass index, c) child subscapular skinfold z-score, d) child lean mass z-score. Outliers were identified, and the analysis was performed with and without outliers, with similar results. In the figure, we show the results preformed with outliers (Mann-Whitney test: D= Difference between the medians; IC 95%).