

**FACTORS CONTRIBUTING TO RICKETS AMONG CHILDREN UNDER-FIVE YEARS' IN EMBU COUNTY, KENYA**

**NAHASON MURIITHI MUCHUKA<sup>1</sup>**  
**WAMBUI KOGI MAKAU<sup>2</sup>**  
**ANGELA ADHIAMBO ANDAGO<sup>2</sup>**  
**SAMUEL KURIA MBUGUA<sup>2</sup>**

<sup>1</sup>Ministry of Health, Kenya

<sup>2</sup>Department of food science, Nutrition and Technology, Faculty of Agriculture, University of Nairobi, P.O Box 29053-00625, Nairobi, Kenya

---

**Abstract**

The objective of the study was to determine the factors contributing to the rickets for children under-five years in Embu county, Kenya. Using retrospective cross-sectional design, 189 mothers with children under-five years with and without rickets were interviewed using a structured questionnaire. Children with rickets were exhaustively sampled while those without rickets were randomly selected as they attend maternal child health and occupation therapy clinics in Embu and Ishiara hospitals. Descriptive statistics, Chi-square, odds ratio and binary regression was applied. Rickets was higher among households with large family size ( $p=0.012$ ), early introduction of complementary feeding (odds ratio (OR)=2.5), consumption of low dietary intake of vitamin D and lack of exposure to sunlight ( $p=0.001$ , OR=9.8). Rickets was higher with decreasing duration of exposure to sunlight and among children who were fully dressed. The most frequently consumed vegetables by the children with rickets was spinach (91%) and those who consumed for more than three days in a week had higher likelihood of having rickets (OR=2.5). Underweight ( $p=0.017$ ), wasting ( $p=0.009$ ) and Depo-Provera ( $p<0.001$ ) predisposed children to rickets. Children from mothers who used Depo-Provera for more than 1 year during preconception period were more likely to have rickets (OR=15.5). In conclusion, lack of exposure to sunlight, use of Depo-Provera for more than one year during preconception period, low consumption of milk and milk product and high consumption of vegetables rich in oxalates such as spinach and early introduction of complementary feeding were major factors contributing to rickets in Embu county.

**Keywords:** Rickets, dietary calcium, vitamin D, Sun exposure, Depot medroprogesterone acetate

## **Introduction**

Rickets is a childhood disorder that occurs due to nutrient deficiency of either primary deficiencies of vitamin D or calcium or combined deficiency of both elements (Fischer, Thacher and Pettifor, 2008). Deficiency of vitamin D lowers intestinal calcium absorption to as low as 10- 15% of the intake especially during periods of active growth (Misra *et al.*, 2008). Lengthy duration of breastfeeding, limited sun exposure, limited dietary intake and poor housing would contribute to the development of rickets (Matsuo *et al.*, 2009, Lucia *et al.*, 2003). Exposure to sunlight in tropical and subtropical climes is generally abundant but deficiency in vitamin D may arise in association with risk factors like covering skin for various reasons such as religious or cultural reasons, darker skin pigmentation and may be atmospheric pollution (Jones *et al.*, 2017). Use of Depo-Provera has been found to lower bone mineral density (BMD) which measures quantity of calcium an individual has in a certain bone (Clark *et al.*, 2006). Depo-Provera lowers BMD by suppression of ovarian production of estradiol which is a sex hormone involved in the development of BMD and attainment of peak bone mass (Clark *et al.*, 2006). Mother who Use of Depo-Provera for more than a year could take as long as 92 months (i.e over 7 years) for them to regain their original bone mineral density (Clark *et al.*, 2006). This study found out that use of Depo-Provera for more than one year was a contributing factor to rickets.

Rickets causes deformities of long bones, weakness of muscles and delayed motor development (Hsu *et al.*, 2017), late teething and walking, delayed sitting poor weight gain, big forehead, bowed lower extremities, rough skin on the stomach and feet, persistence fever and diarrhoea and hypersensitive feet (Billoo *et al.*, 2009). It is increasingly becoming a major problem in health and is one among the causes of disability in low income countries (Ahmed *et al.*, 2011). However, the same trend is emerging in high income countries such United State America and United Kingdom among others major in dark skinned immigrant population (Thacher *et al.*, 2013).

One billion people worldwide are victims of rickets with higher number of them being children suffering from severe malnutrition attributed to famine or starvation in the early stages of childhood (Taylor, 2008). In Kenya, hospitals continue to record increased cases of rickets as observed in Kiambu district hospital where about 100 cases of rickets are recorded every month, and in Kenyatta National Hospital two to three cases are recorded daily (Bwibo, 2003). An increased trend was noted in Embu where rickets clinical signs were not observed

in 1980's study. However, studies carried out later in highland parts in 2000 to 2003 shown that about 7% of children aged 1 -4 years had clinical rickets (Neumann and Bwibo, 2008).

Rickets continues to be a public health problem in Embu county despite abundance of sun shine most of the year and also dominated with agricultural farming. The study was to determine the contributing factors to rickets among children under-five years old attending Embu and Ishiara hospitals. It is importance to identify early enough the contributing factors to rickets in order to be able to provide prophylactic services to prevent the subsequent bone damages and delayed motor development as result of rickets as opposed to therapeutic management service for rickets in children.

## **Methods**

### **Study setting**

The study was conducted in Embu level five and Ishiara level four hospitals, located in Embu county, Kenya. The county occupies an area of 2,818 km<sup>2</sup> and has a population of 516,212 (49% - male, 51% - female). The county borders Tharaka Nithi to the north, Kitui to the east, Murang'a to the south west and Kirinyaga county to the west.

### **Study design**

The study was a retrospective, cross sectional study. The study subject were children with rickets (89) and without rickets (89) and their mothers. The children with rickets were exhaustively selected at the two hospitals while attending the facilities for health care service at occupational therapy and maternal child health clinic. While children without rickets were randomly selected by choosing every second child following the selection of the child with rickets. The sample size was calculated using the Fischer et al formula 1991. The study was conducted in the months of July and August 2017.

### **Data collection**

A structured questionnaire was administered to the biological mother of the child to collect data which included: demographic and socio-economic data, dietary and breastfeeding practices, sun exposure practices, co-morbidity status, anthropometric assessment and family planning method used by the mothers during preconception period. Trained clinical officers and nurses deployed in Embu and Ishiara hospitals determined the rickets cases by physical examination, radiographs and laboratory examinations. The mothers report on the wellbeing

of the child determined the co-morbidities. The dietary intake of the nutrient of interest (vitamin D and calcium) was determined using 24 hour recall questionnaire. Kitchen food scales were used to determine the volume equivalent of foods and the scales were calibrated on regular basis to ensure accurate readings. The research assistants were well trained on how to accurately collect data and on the best practices and ethical issues to ensure quality of data. Research assistant conducted interviews and filling questionnaires with close supervision. Completeness of questionnaires was checked every evening to ensure that they were filled well and problems encountered rectified. The approval by the Embu and Ishiara hospitals was given before the start of data collection. Informal consent was obtained from every mother of the study to ensure participation without any coercion.

### **Statistical Data Analysis**

The statistical package for social sciences (SPSS) version 20 was used for data entry, data cleaning and data analysis. The 24 hour dietary recall and food frequency data was analysed using Nutri-Survey 2007 software to determine whether the children are meeting their recommended dietary allowances (RDA). Anthropometric data measurements were analysed using ENA for SMART 2011. Means and standard deviation of vitamin D and calcium daily intake were computed using descriptive statistics and Chi-square test, where if the cell had less than five count Fischer exact test was used. For the cells that had more than five counts Pearson chi-square was used. The level of significance was set at 95%. Odds ratio and binary regression were used to determine the likelihood of the children to develop rickets or the association of rickets with these factors.

### **Results**

#### **Demographic and socio-economic characteristics of children with rickets**

The occurrences of rickets in male children and female children was found to be equal with ratio of 1:1. Most of the children who had rickets (39.3%) were 6-17 months old. Analysis of the family size of the household showed that most of the children with rickets were from household with family size with greater than 4 members ( $p=0.012$ ). Regarding the mother's occupation, significant difference was showed between the occurrences of rickets and the mothers occupation ( $p=0.037$ ). Most of the children with rickets were from mothers who were self-employed. There were no significant differences between income and the occurrence of rickets ( $p=0.552$ ).

**Table 1. Rickets in relation to family size, occupation and income of the mother**

| Characteristic                         | Children with rickets<br>n=89,(%) | Children without rickets<br>n=89,(%) | p- value |
|--|-----------------------------------|--------------------------------------|----------|
| <b>Family size</b>                     |                                   |                                      |          |
| <4                                     | 37.1                              | 55.1                                 | 0.012    |
| >4                                     | 62.9                              | 44.9                                 |          |
| <b>Occupation of the mother</b>        |                                   |                                      |          |
| Salaried employment                    | 15.7                              | 23.6                                 | 0.037    |
| Farmer                                 | 21.3                              | 13.5                                 |          |
| Self-employment                        | 41.6                              | 28.1                                 |          |
| Casual labourer                        | 9.0                               | 7.9                                  |          |
| Unemployed                             | 12.4                              | 19.7                                 |          |
| <b>Income</b>                          |                                   |                                      |          |
| 0 – 5000                               | 10.1                              | 28.1                                 | 0.552    |
| >5000 – 15000                          | 43.8                              | 34.8                                 |          |
| >15000 – 30000                         | 32.6                              | 20.2                                 |          |
| >30000                                 | 13.5                              | 16.9                                 |          |
| <b>Gender of the children</b>          |                                   |                                      |          |
| Male                                   | 50.6                              | 64.0                                 | 0.690    |
| Female                                 | 49.4                              | 36.0                                 |          |
| <b>Age group of children in months</b> |                                   |                                      |          |
| <6                                     | 2.2                               | .0                                   | 0.088    |
| 6-17                                   | 39.3                              | 54.0                                 |          |
| 18-29                                  | 36.0                              | 36.0                                 |          |
| 30-41                                  | 19.1                              | .0                                   |          |
| >41                                    | 3.4                               | 5.6                                  |          |

**Care practices and nutrition status of the children with rickets and those without rickets**

As shown in table 2, most of the children were exclusively breastfed, however, there was a significant difference between children with rickets and those without rickets (p=0.018). Children who were not exclusively breastfed were more likely to have rickets. Greater proportion of children who were underweight (33.7%) and those who were wasted (28.1%) had rickets compared to those who were underweight (18.0%) and wasted (12.4%) and did not have rickets. Sun bathing was highly practiced to children without rickets (97.8%) compared to 83.1% of children with rickets. Close to seventeen percent (16.9%) of children with rickets were not sun bathed at all compared to only 2.2% of the children without rickets. Very significant difference was showed between children with and those without rickets and the sun bathing (p=0.001). The duration of time the children were

exposed to sunlight showed significant difference between the children with and without rickets (0.007), with those who were exposed for less than 15 minutes more likely to have rickets.

**Table 2 Care practices and nutrition status of the children with rickets and without rickets**

| Characteristic                          | Children with rickets<br>n=89, (%) | Children without rickets<br>n=89,(%) | p-value |
|---|------------------------------------|--------------------------------------|---------|
| <b>Exclusive breastfeeding</b>          |                                    |                                      |         |
| Yes                                     | 65.2                               | 80.9                                 | 0.018   |
| No                                      | 34.8                               | 19.1                                 |         |
| <b>Underweight</b>                      |                                    |                                      |         |
| Yes                                     | 33.7                               | 18.0                                 | 0.017   |
| No                                      | 66.3                               | 82.0                                 |         |
| <b>Stunting</b>                         |                                    |                                      |         |
| Yes                                     | 26.2                               | 31.5                                 | 0.744   |
| No                                      | 70.8                               | 68.5                                 |         |
| <b>Wasting</b>                          |                                    |                                      |         |
| Yes                                     | 28.1                               | 12.4                                 | 0.009   |
| No                                      | 71.9                               | 87.6                                 |         |
| <b>Exposure to sunlight</b>             |                                    |                                      |         |
| Yes                                     | 83.1                               | 97.8                                 | 0.001   |
| No                                      | 16.9                               | 2.2                                  |         |
| <b>Duration of exposure to sunlight</b> |                                    |                                      |         |
| Not exposed                             | 16.9                               | 2.2                                  | 0.007   |
| <15 minutes                             | 14.6                               | 12.4                                 |         |
| >15 – 30minutes                         | 30.3                               | 32.6                                 |         |
| >30minutes                              | 38.2                               | 52.8                                 |         |

**Mode of dressing for children when exposing to sunlight**

As shown in the table 3, children were sun bathed while dressed differently. Children who were exposed to sunlight while fully dressed had higher likelihood of having rickets (OR=1.6). The mode of dressing between children with and without rickets showed a significant different (p=0.002). The study generated a rule of exposure to sunlight which showed various percentages of body surface area in relation to sunlight exposure. The rule argues that when children are exposed to sunlight while fully undressed the body has 100% exposure to sunlight, if fully dressed the child will only have 19% of body surface area exposed to sunlight. When a child is exposed with pant and pant and vest the child’s body surface area is exposed 94% and 68% respectively.

**Table 3 Mode of dressing during sun bathing and occurrences of rickets for children under-five years**

| Mode of dressing | % of body exposure to sunlight | Children with rickets<br>n=89,(%) | Children without rickets<br>n=89,(%) | Odds ratio |
|------------------|--------------------------------|-----------------------------------|--------------------------------------|------------|
| Fully undressed  | 100                            | 6.7                               | 11.2                                 | 0.6        |
| Pant only        | 94                             | 11.2                              | 14.6                                 | 0.7        |
| Pant and vest    | 68                             | 34.8                              | 50.6                                 | 0.5        |
| Fully dressed    | 19                             | 30.3                              | 21.3                                 | 1.6        |

**Distribution of mothers by family planning used during preconception period**

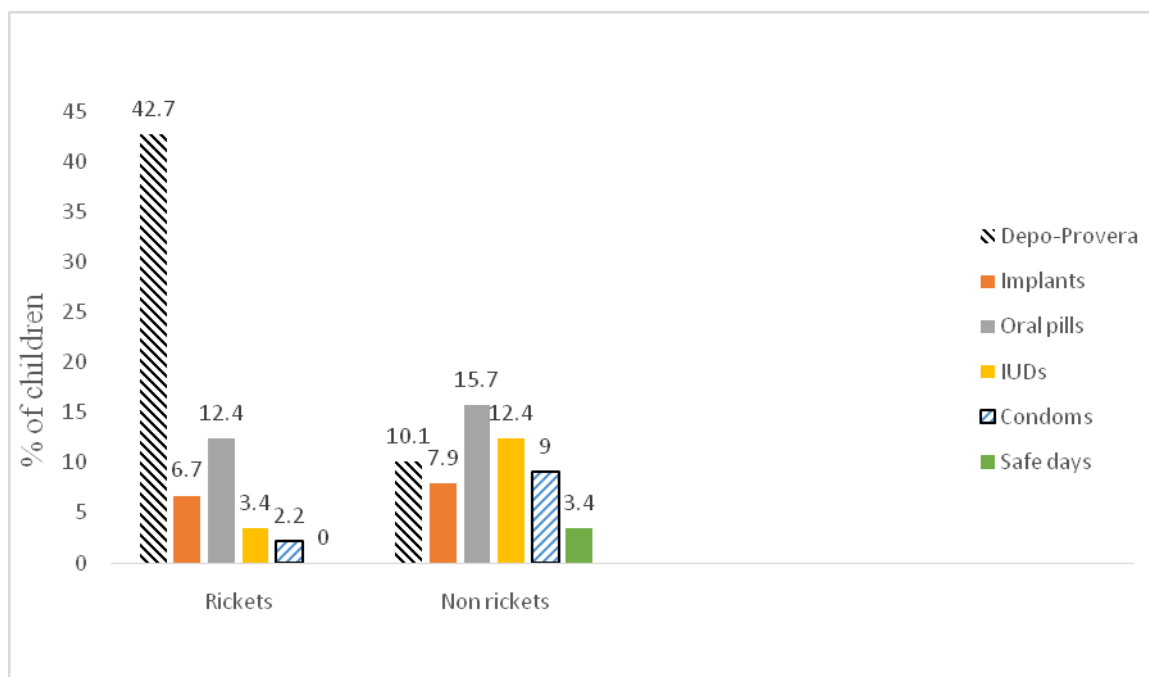
Table 4 showed that greater proportion of mothers 112 (62.9%) under the study were using family planning before conception of the index child. Around thirty seven percent 66 (37.1%) of the mothers did not use any kind of family planning during preconception period. A big proportion of the mothers who used family planning methods used Depo-Provera.

**Table 3 Distribution of mothers by family planning method used during preconception period**

| Family planning methods | Frequency<br>N=178 | Percent<br>% |
|-------------------------|--------------------|--------------|
| Depo-Provera            | 47                 | 26.4         |
| Implants                | 13                 | 7.3          |
| Oral pill               | 25                 | 14.0         |
| Intra-uterine devices   | 14                 | 7.9          |
| Condoms                 | 10                 | 5.6          |
| Safe days               | 3                  | 1.7          |
| No method               | 66                 | 37.1         |

**Occurrences of rickets by the type of family planning used by mothers during preconception period**

Mothers used various types of family planning during their preconception period. The figure 4.5 shows that most of the children who had rickets, were from the mothers who had used Depo-Provera as method of family planning in their preconception period. For the mothers who used safe days as a method of family planning 3(3.4%), none of their children had rickets. Very significant different was showed between the occurrences of rickets and the use of family planning ( $p < 0.001$ )



**Figure 1 Occurrences of rickets by the type of family planning used by mothers during preconception period**

**Relationship of family planning methods used by the mothers during preconception period and the occurrences of rickets**

Depo-Provera was mostly used by the mothers with children who had rickets, and it shows very significance difference ( $p < 0.001$ ), while other methods used by mothers did not show any significance difference in the occurrences of rickets. This implies that children from mothers who used Depo-Provera as method of family planning during preconception period were susceptible to rickets as compared to those who did not use it.

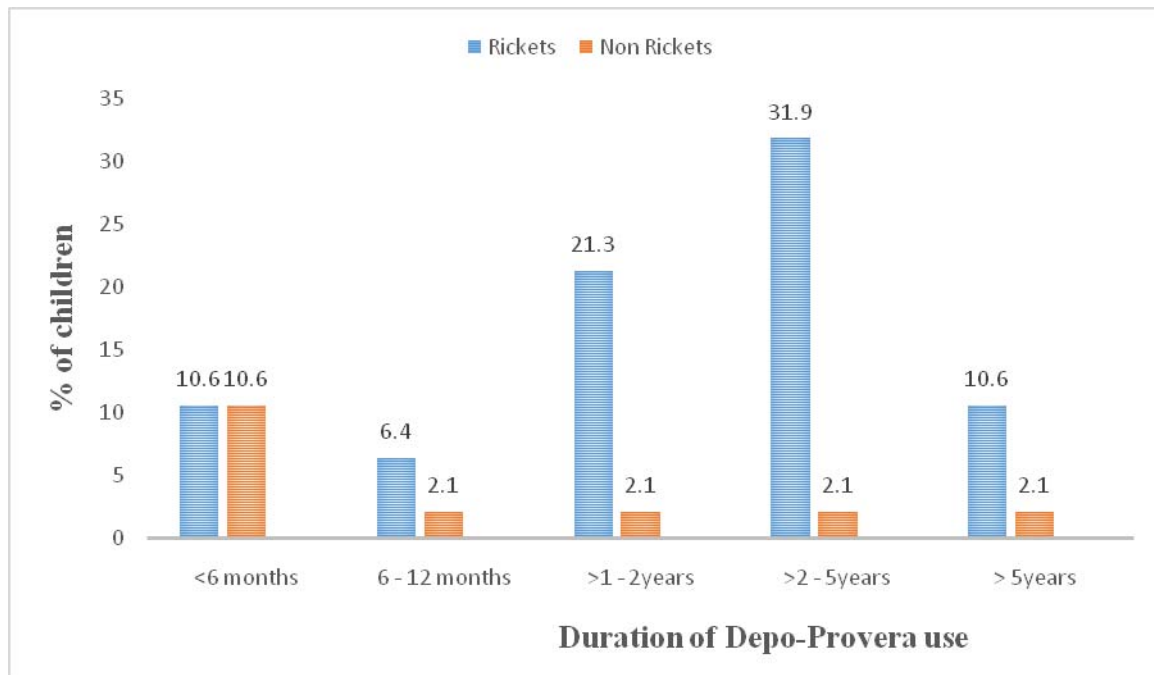
**Table 4 Relationship of family planning methods used by the mothers during preconception period and the occurrences of rickets**

| Family planning | Children with rickets<br>n=89,(%) | Children without rickets<br>n=89,(%) | p-value |
|-----------------|-----------------------------------|--------------------------------------|---------|
| Depo-Provera    | 42.7                              | 10.1                                 | 0.000   |
| Oral pills      | 12.4                              | 14.6                                 | 0.661   |
| Implants        | 6.7                               | 7.9                                  | 0.773   |
| IUDs            | 3.4                               | 12.4                                 | 0.048   |
| Condoms         | 2.2                               | 10.1                                 | 0.057   |



**Length of use for Depo-Provera**

Most of the mothers who used Depo-Provera as a method of family planning during preconception period for more than one year, their children developed rickets. This shows that the longer the use of Depo-Provera during preconception period the more the likelihood of the children to develop rickets (OR=15.5).



**Figure 2 Occurrences of rickets in relation to the duration Depo-Provera has been used**

**Mean daily dietary intake of calcium, phosphorus and vitamin D and the occurrences of rickets**

The table 4.18 shows that the mean daily dietary intake of calcium was  $687.9 \pm 197.7$  mg (mean  $\pm$ SD) and  $749.6 \pm 231.1$  mg (mean  $\pm$ SD) for children with rickets and without rickets respectively (p-value=0.276) which showed not statistical significant. The mean daily dietary intake for vitamin D was  $1.4 \pm 2.0$   $\mu$ g for children with rickets and  $0.4 \pm 1.1$   $\mu$ g for the children without rickets (p-value=0.024) this showed that there was a statistical difference between vitamin D and the occurrences of rickets.

**Table 5 Mean daily dietary intake of calcium, phosphorus and vitamin D and the occurrences of rickets**

| Food nutrient    | Rickets (n=17)<br>mean ± SD | Non rickets (n=8)<br>Mean ± SD | p-value |
|------------------|-----------------------------|--------------------------------|---------|
| Calcium (mg)     | 687.9 ±197.7                | 749 ±231.1                     | 0.276   |
| Phosphorous (mg) | 1182.9 ±502.4               | 1173.7 ±360.1                  | 0.302   |
| Vitamin D (µg)   | 1.4 ±2.0                    | 0.4 ±1.1                       | 0.024   |

**Factors associated to rickets in Embu County, Kenya.**

Binary logistic regression analysis identified the following as the contributing factors to rickets; lack of exposure to sunlight and the duration of exposure, use of Depo-Provera for more than one year, early introduction of complementary foods and lack of exclusively breastfeeding, high consumption of spinach and low use of milk and milk product, underweight and wasting, occupation of the mother and the family size.

**Table 6. Logistic regression model for risk factors to rickets among children under-five years**

| Variables                                   | Beta   | Sig   | OR     | 95% C.I for OR<br>Lower- Upper |
|---|--------|-------|--------|--------------------------------|
| Underweight                                 | 0.709  | 0.052 | 2.031  | 0.994 – 4.152                  |
| Wasting                                     | 1.031  | 0.016 | 2.805  | 1.209 – 6.509                  |
| Exposure to sunlight                        | 2.281  | 0.043 | 9.785  | 1.073 - 89.215                 |
| Exposure to sunlight while fully dressed    | -2.526 | 0.006 | 0.080  | 0.013 – 0.479                  |
| Exposure to sunlight less than 15 minutes   | 0.868  | 0.024 | 2.383  | 1.121 – 5.065                  |
| Depo-Provera use                            | 1.895  | 0.000 | 6.654  | 2.902 – 15.255                 |
| Use of Depo-Provera for more than 1 year    | 2.738  | 0.000 | 15.456 | 3.332 – 71.905                 |
| Early introduction of complementary feeding | 0.923  | 0.018 | 2.515  | 1.173 – 5.405                  |
| Exclusively breastfed                       | 0.937  | 0.026 | 2.553  | 1.117 - 5.837                  |
| High consumption of spinach                 | 0.898  | 0.044 | 2.456  | 1.024 – 5.886                  |
| Low consumption of milk and milk product    | 0.917  | 0.028 | 2.502  | 1.104 – 5.673                  |
| Household size                              | -.826  | 0.010 | 0.438  | 0.234 – 0.821                  |
| <b>Occupation</b>                           |        |       |        |                                |
| Farmer                                      | 1.327  | 0.012 | 3.8    | 1.346 – 10.555                 |
| Self-employed                               | 1.133  | 0.011 | 3.1    | 1.298 – 7.428                  |

## **Discussion**

The current study showed that the larger family size the higher the occurrence of rickets among children under-five years. This is concurring with the study conducted in Riyadh which found that children with rickets were from families with more family members (Meigied and Karim, 2011). This was attributed to increased family needs at the expenses of other vulnerable family members including children under-five years. Regarding the occupation of the mothers, rickets was found to be higher among children of self-employed mothers. Occupation of the mother defines the total time spent with the children such that those busy in their business have limited time to spend with their children, hence, this affects the dietary intake and care practices of the children.

The study showed that male children are equal to female children with ratio of 1:1. This proportion differed with similar studies conducted in Kiambu (Theuri, 2017) and Kenyatta National Hospital (Kinuthia *et al*, 1994) which indicate that male children were slightly highly affected than female children with ratio of 1.2:1. Children less than 17 months were more prone to rickets. This concurs with study in Jordan where young children were more susceptible to rickets (Khan *et al*, 2001). In comparison to exclusively breastfeeding, non-exclusively breastfed children for six months were more associated with rickets. These study results concur with previous study in Gaza strip which showed that exclusive breastfeeding could only be a risk factor if it is beyond six months without vitamin D supplementation (Yassin, 2010). This is because the breast milk gives infants nutritional requirement in the first 6 months of life and play an important role in keeping children healthy and early supplemental nutrition can have a negative influence of infant growth (Hoseini *et al.*, 2014).

This study indicated that early introduction of complementary foods was a risk factor to the occurrence of rickets among children under-five years. According to world health organisation, complementary feeds should be introduced after six months of birth. The high frequency of consumption of spinach which is rich in calcium content but also contains oxalic acid which interferes with calcium absorption, has showed the association with rickets. According to Andrew (1976) 125g of spinach contain 750mg of oxalate, this significant relationship shows a potential risk. There was low intake of daily foods, good sources of vitamin D which was below the recommended intake of 5µg per day (Holick *et al*, 1992). The findings indicate that low frequency in consumption of milk and milk products had an association with development of rickets.

Children and infants who were not exposed to sunlight have been associated with rickets than those exposed. This relationship has been confirmed in this study as children and infant who were not exposed to sunlight were more susceptible to rickets compared to those not exposed. Presence of rickets is more prevalent in population that covers children fully mainly for cultural or religious reason (Unavar and Buyukgebiz,2010). Religion did not significantly relate to occurrence of rickets in this study, therefore, infants were covered for reason independent of religion. Children and infants who had spent less time under the sun were more prone to rickets. This is in line with the study that showed that children and infants being kept indoors were associated with rickets (Neumann and Bwibo,2008). Lack of exposure to sunlight, exposing children and infants while fully dressed and duration of exposure during early life has more influence on development of rickets as some mothers fully dressed and exposed their children to sunlight for less than 15 minutes. Exposure to UVB in sunlight is essential for cutaneous synthesis of vitamin D and is the body's main source of vitamin D. The active hormonal form 1,25-dihydroxyvitamin D is required for calcium (Ramagopalan *et al*,2011).The study shows poor exposure practices to sunlight which have contributed low vitamin D, hence, making children more susceptible rickets.

Depo-Provera is one of the most used contraceptive and its currently used by more than nine millions women in most of developed and developing countries(Kyvernatakiset *al.*, 2006). This study indicates the use of Depo-Provera during preconception period by the mothers have showed an increased risk of rickets to children born after, particularly with prolonged period of use exceeding one year prior to conception. Previous study has showed that prolonged use of Depo-Provera lowers bones mineral density. Mother who Use of Depo-Provera for more than a year could take as long as 92 months (i.e over 7 years) for them to regain their original bone mineral density(Clark *et al.*, 2006), this indicates the almost significant association as potential risk.

## **Conclusions**

From the discussion, it is clear that rickets can be considered a multi factorial condition; in which lack of exposure to sunlight, use of Depo-Provera for more than one year, early introduction to complementary foods, high consumption of food rich in oxalate such as spinach, low consumption of food rich in vitamin D such as milk and milk products and lack of exclusive breastfeeding for the first six months of birth are predisposing factors.

Furthermore, it is paramount to educate the mothers and the community on the essence of sun basking and the best practices to ensure synthesis of vitamin D in the skin.

### **Acknowledgements**

The researchers appreciate the Department of Food Science, Nutrition and Technology, University of Nairobi for technical support, Ministry of Health Embu county for granting study leave to Mr. Nahason Muriithi and mothers and children from Embu county who made the study possible.

### **References**

1. Ahmed, S. F. *et al.* (2011) 'Recent trends and clinical features of childhood vitamin D deficiency presenting to a children's hospital in Glasgow', *Archives of Disease in Childhood*, 96(7), pp. 694–696. doi: 10.1136/adc.2009.173195.
2. Andrew S. 1976. Introduction to Organic Chemistry. New York: Macmillan.
3. Billoo, A. G. *et al.* (2009) 'Comparison of oral versus injectable vitamin-D for the treatment of nutritional vitamin-D deficiency rickets', *Journal of the College of Physicians and Surgeons Pakistan*, 19(7), pp. 428–431. doi: 07.2009/JCPSP.428431
4. Bwibo, N. O., & Neumann, G. N. (2003). The need for animal source foods by Kenyan children. *Journal of Nutrition*, 133:3936-3940.
5. Clark, M. K. *et al.* (2006) 'Bone mineral density loss and recovery during 48 months in first-time users of depot medroxyprogesterone acetate', *Fertility and Sterility*, 86(5), pp. 1466–1474. doi: 10.1016/j.fertnstert.2006.05.024.
6. DeLucia, M. C., Mitnick, M. E., & Carpenter, T.O. (2003). Nutritional rickets with normal circulating 25-hydroxyvitamin D: A call for reexamining the role of dietary calcium intake in North American Infants. *Journal of Clinical Endocrinol Metabolism*, 88(8):3539-3543
7. Fischer, P. R., Thacher, T. D. and Pettifor, J. M. (2008) 'Pediatric vitamin D and calcium nutrition in developing countries', pp. 181–192. doi: 10.1007/s11154-008-9085-1.
8. Holick M, Shao O, Liu W, Chen T. 1992. The Vitamin D Content of Fortified Milk and Infant Formula. *New England Journal of Medicine*. 326:1178–1181.
9. Hoseini, B. L. *et al.* (2014) 'Maternal Knowledge and Attitude toward Exclusive Breast Milk Feeding ( BMF ) in the First 6 Months of Infant in Mashhad', *International journal of Pediatrics*, 2(3), pp. 63–69. doi: 10.22038/ijp.2014.2484.
10. Hsu, J. *et al.* (2017) 'The relationship of maternal bone density with nutritional rickets in Nigerian children ☆', *Bone*. Elsevier Inc., 97, pp. 216–221. doi: 10.1016/j.bone.2017.01.026.
11. Jones, K. D. J. *et al.* (2017) 'Vitamin D deficiency causes rickets in an urban informal settlement in Kenya and is associated with malnutrition', (February), pp. 1–8. doi: 10.1111/mcn.12452.
12. Khan K, Khattak A, Rehman G, Shah U. 2001. Study of Rickets in Admitted Patients at Lady Reading Hospital, Peshwar. *Journal of Paediatric Medicine*. 18:52–53. Kinuthia
13. Kinuthia D, Nyakundi P, Orinda D. 1994. Clinical Aspects and Causes of Rickets in a Kenyan Population. *East Africa Medical Journal*. 71:536–542.
14. Kyvernitakis, I. *et al.* (2017) 'The impact of depot medroxyprogesterone acetate on fracture risk : a case-control study from the UK', *Osteoporosis International*. *Osteoporosis International*, pp. 291–297. doi: 10.1007/s00198-016-3714-4.
15. Matsuo, K., Mukai, T., Suzuki. S., & Fujieda, K. (2009). Prevalence and risk factors of vitamin D deficiency rickets in Hokkaido, Japan. *Pediatrics International*, 51(4):559-562.
16. Megeid, F.Y.A., & Karim, B. O. I. (2011). Genetic plays apart in the causation of vitamin D deficiency rickets at Riyadh. *World Journal Medical Sciences*, 6(2): 74-80.
17. Misra, M. *et al.* (2008) 'Vitamin D Deficiency in Children and Its Management: Review of Current Knowledge and Recommendations', *Pediatrics*, 122(2), pp. 398–417. doi: 10.1542/peds.2007-1894.
18. Neumann, G. N., & Bwibo, N. O. (2008). Clinical rickets in rural Kenyan preschoolers. *The FASEB Journal*, 22:149.1
19. Ramagopalan SV, Dymant DA, Cader MZ, Morrison KM, Disanto G, Morahan JM, Berlanga-Taylor AJ, Handel A, De Luca GC, Sadovnick AD, et al. Rare variants in the CYP27B1 gene are associated

- with multiple sclerosis. *Ann*
20. *Neurol* 2011;70:881–6.
  21. Taylor J. 2008. Defining Vitamin D Deficiency in Infants and Toddlers. *Arch Pediatr Adolesc Med.* 162:583– 584.
  22. Thacher, T. D. *et al.* (2013) ‘Increasing incidence of nutritional rickets: A population-based study in olmsted county, minnesota’, *Mayo Clinic Proceedings*. Mayo Foundation for Medical Education and Research, 88(2), pp. 176–183. doi: 10.1016/j.mayocp.2012.10.018.
  23. Theuri, A. W. (2017) ‘Under-fives Rickets in a Tropical Dairy Farming Region, Kiambu County, Kenya.
  24. Unuvar, T., & Buyukgebiz, A. (2010). Nutritional rickets and vitamin D deficiency in infants, children and adolescents. *Pediatric Endocrinology Reviews*, 7(3):283- 91.
  25. Yassin, M. M. (2010) ‘Risk factors associated with nutritional rickets among children aged 2 to 36 months old in the Gaza Strip : a case control study’, 3(1).