ASSOCIATION BETWEEN EARLY LIFE MALNUTRITION AND THE SIZE OF LUMBAR SPINAL CANAL AMONG ADULTS OF COASTAL REGION, KENYA

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ABSTRACT

Background: The aetiology of chronic low back pain is largely unknown. A high prevalence of developmentally narrow canals may explain some of the aetiology or the accompanying nervous tissue compression that often accompany.
Objective: To determine the relationship between early life malnutrition and the development of lumbar spinal canal. A relationship between early life malnutrition and developmental narrowing would indirectly incriminate such predictors as poverty, aridity and human development which can be reduced by policy and strategy.
Methods: This was an observational cross sectional survey. The participants were screened for Early Life Malnutrition (ELM) using a semi-structured questionnaire. Various observations and measurements were made which included measurement of the dimensions of the spinal canal on MRI or CT scans of the lumbosacral spine. The cross sectional area was used for determination. The frequencies and means were compared in the group with ELM and the one without.
Results: The results showed the prevalence of ELM in the adult population of coastal Kenya to be 29% and the prevalence of Developmental Lumbar Spinal Canal Stenosis (DLSS) was16%. Those with ELM had a higher prevalence of DLSS (20%) than those without (14%), p = 0.003. There were differences in DLSS dimensional means between those with ELM and those without, depth (P = 0.046), cross sectional area (P = 0.042), and in width (P = 0.176). There was a strong negative linear relationship between the canal depth (APD), r =-0.68, cross sectional area (CSA), r = -0.65, and a moderate negative linear relationship with the canal width (TRD), r = -0.50.
Conclusions: The present study shows a high prevalence rate of ELM and DLSS in the study population. There is a higher prevalence of DLSS in those with ELM. The two shows a strong negative linear relationship between ELM and DLSS. ELM may partly be responsible for developmentally narrow canals.

Key words: Early-life-malnutrition, Developmental narrowing, Lumbar spinal canal stenosis, Prevalence, Low back pain, Sciatica

INTRODUCTION

Low back pain affects many individuals in different populations, with profound effects on the well-being of those affected individuals. Low Back Pain (LBP) is often a cause of significant morbidity and financial strain, affecting work performance and social responsibilities. A global review of the prevalence of low back pain in the adult general population has shown its point prevalence to be approximately 12% and a lifetime prevalence of approximately 40% (1). Out of all 291 conditions studied in the Global Burden of Disease 2010 Study, LBP ranked highest in terms of disability and sixth in terms of overall burden. The global point prevalence of LBP was 9.4% (95% CI 9.0 to 9.8) (2). The majority of patients with chronic low back pain have no specific cause and are said to suffer idiopathic or mechanical LBP. The condition is often assumed to be degenerative in nature yet controlled studies have indicated that there is minimal correlation between clinical symptoms and radiological signs of degeneration (3).

A high prevalence of developmentally narrow canals may explain some of the aetiology or the accompanying nervous tissue compression that often accompany LBP. Malnutrition is postulated in this study to cause or contribute to developmental

narrowing of the lumbar spinal canal. Malnutrition occurring any time during embryonic, foetal or early childhood periods may cause changes at themolecular, cellular, and organ levels. These changes are likely to result to aberration in function, shape, size or various combinations in the spinal canal. McCance in 1960 (4), studied the long term effect of early nutrition in rats; this was followed by numerous animal studies that showed that nutrition in early life can induce lifetime effects on metabolism, growth and development with consequences on major disease processes such as cardiovascular, obesity osteoporosis and diabetes mellitus among others (5-7). Changes in size, shape and general topography of bones are obvious in adult life and can be observed clinically or/and radiologically. Some of the visible abnormalities are stunting, wasting and small head circumference. Others are occult abnormalities that will only be discerned radiologically, such as spina bifida, trefoilness of the spinal canal and spinal stenosis. Very little is known about the epidemiology of developmental stenosis in the general African population.

Developmental stenosis may remain asymptomatic until the onset of degenerative changes at the disc, ligament or facetal joint level (8) when the already narrow canal lumen is further compromised. Therefore, degenerative changes will make a hitherto quiescent developmentally narrow canal severely symptomatic in adulthood. The common presentation is severe low back pain accompanied by muscle weakness, reflex alterations, gait disturbances, bowel or bladder dysfunction, motor and sensory changes, radicular pain or atypical leg pain, and neurogenic claudication.

Computerized imaging (particularly MRI and CT scanning) has made accurate measurement of the dimensions of the spinal canal possible. Digitalization has also emerged with soft ware for direct measurement which minimises error. Apart from demonstrating the vertebra canal in great detail, these novel imaging modalities also reveal abnormal developmental changes in the vertebrae itself and the surrounding tissues such as disc degeneration, hypertrophied ligamentum flavum, listhesis and spondylolysis, subarticular and or foramina narrowing which form part of the pathology of stenosis.

This study was set out to determine the association of ELM and DLSS among residents of the Coastal region of Kenya. Alleviating ELM would then reduce DLSS and in consequence chronic low pain with its debilitating nervous tissue compression.

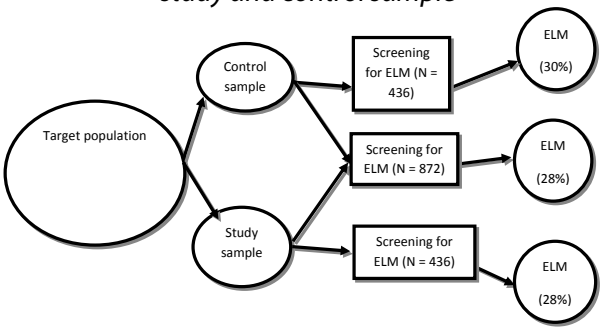
MATERIALS AND METHODS

The study received appropriate approvals from the involved institutions before commencement. The study was an observational cross sectional survey conducted from 2nd October 2017 to 13th January 2018 in seven centres. The data collection centres were radiology departments of these institutions. Participants were recruited from patients presenting for radiological examination. All study participants were voluntary individuals who consented to the study. All the participants were adult black Africans who were born and spent their first 5 years of life in the coast region. Those not included in the study were people of non-African or of mixed race, those with musculoskeletal disorders such as hip dysplasia or scoliosis, those that were syndromic (dwarfism and achondroplasia), and those with prior spine surgery, spine fractures, infection or tumours. Dysraphism was not excluded but tarried as part of the study.

The study used a semi-structured questionnaire which enquired on their bio data, family history; childhood experiences particularly sicknesses and lack of food among others. Required on site observations and measurements were done and entered on the same individualised questionnaires. Data was collected simultaneously on the exposure variables (ELM predictors) as well as the outcome (spinal canal dimensions). The independent variable (ELM) was represented by composite markers of parental poverty, reduced nutrition, and perceived manifestations of malnutrition that are discernible or measurable (stunting, enamel hypoplasia and spina bifida). From these varied variables a tool was constructed to screen for ELM. The tool is a scoring card that incorporated historical data on food supply, childhood illnesses, markers of parental empowerment and developmental attributes that are observable on an adult that may be attributed to early life malnutrition. The scoring card had ten variables which were scored according to the ability to predict malnutrition. This tool is weighted so that various variables attract different values determined after internal validation and screening for reliability. The maximum total score was 400 points. A participant scoring 200 points and above was deemed to have suffered ELM and was placed in Group 1. Those who scored less than 200 were placed in Group 2. The tool was internally validated and found reliable during piloting with 114 participants. Figure 1 demonstrates the methodology for ELM screening.

Figure 1

Demonstrates the methodology for ELM screening in study and control sample

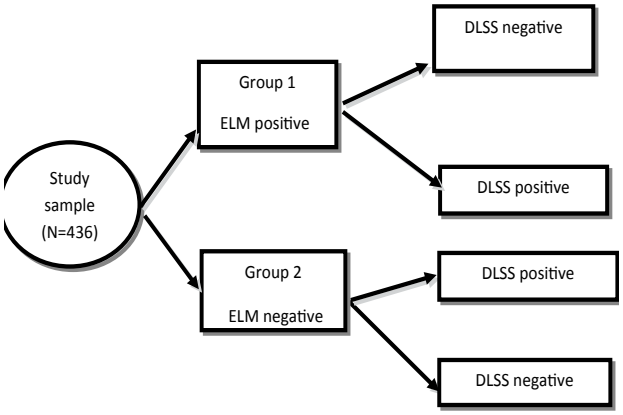


The total sample for ELM determination was 872 participants made of 436 study participants and a matched control of 436 participants. The study group was considered pre-selected because they had a condition requiring CT or MRI scanning, hence the control. This first step was for determination of ELM prevalence as shown in Figure 1.

The second step was to determine the prevalence of DLSS in the study group only (N=436). This group was divided into two, those ELM positive and those who are negative. The dependent variable, DLSS was measured quantitatively by determining the width and depth. Axial and sagital MRI or CT scans of the lumbosacral spine were analysed in 436 participants. The scans were scaled at source to allow direct manual measurement of the desired parameters where the digital measurement was not possible. Measurements were done at the interpedicular level of every vertebra (lumbar 1 to 5). The anteroposterior and transverse diameters of the spinal canal were measured at the interpedicular level. This level considered more precise than the other levels (suprapedicular, infrapedicular or disc level) due to avoidance of inaccurate measurements resulting from scoliosis or improper patient positioning (9).

Figure 2

Demonstrates the methodology for DLSS screening



After all the measurements were obtained, the means and z-scores for each measurement were calculated. The z-scores were calculated from the sample mean, and all measurements below -2 standard deviations were considered to indicate DLSS. There is great variability in the size of the spinal canal in various populations and it is recommended that the population is compared within itself not from the value references found in the literature (10).

Statistical analysis: All data was entered into standardized forms on worksheets prepared for raw data entry and subsequently analysed. The data was analysed using IBM SPSS version 20.0 (SPSS Inc., Chicago, Illinois, US). Descriptive statistics on IBM SPSS were used to analyse for frequencies and central tendency (mean, median and mode) and dispersion (standard error, standard deviation, range and sample variance). In comparing of proportion chi-square statistics in cross-tabulation was used. When comparing means, for two groups, independent-samples t-test or simply means in SPSS was used; and when comparing means with many levels, One-Way ANOVA in SPSS was used. Odds ratio was used to test for any associations. A P value <0.05 was considered statistically significant.

RESULTS

For screening for ELM, a study sample of 436 participants (with CT or MRI scans) was controlled by a matched sample of participants (matched for age and gender) without the need for spine scanning; a total of 872 participants from astudy population of 1198 recruitments. In this study 50.3% of the participants were males and 49.7% female. The mean age was 43.2 years and 52% were aged between 30 and 44 years.

All the participants were screened for ELM. The prevalence of ELM in the study sample was 28% and 30% in the control sample with an average of 29% in the general population. Chi-square statistics in cross tabulation showed no statistical difference in ELM prevalence between the two samples (P =0.1244) (Table 1).

Table 1

ELM Screening

ELM	Absent	Present	Total	(%)
Study sample	315	121	436	28
Control sample	306	130	436	30
Total	621	251	872	29
		P = 0.1244		

In the study sample Group 1 consisted of 121 (ELM positive) and Group 2 had 315 (ELM negative). Both groups had the dimensions of the spinal canal determined; the AP diameter (depth), the transverse diameter (width) and the cross sectional area was calculated from the two orthogonal diameters. The z scores of these measurements were calculated for accurate comparisons of various dimensions. Any individual with a measurement equal to or less than -2 standard deviations (-2sd) in any of the three parameters were considered to have Developmental Lumbar Spinal Canal Stenosis (DLSS).

There were differences in means in all the measurements. Independent t-test in SPSS showed the difference in means to be statistically significant for the depth (P = 0.046) and cross sectional area (CSA) (P = 0.042) and not significant for width (P = 0.176) (Table 2).

Table 2

T-test for various means

	Means		
	Group 1	Group 2	T-test (2 tailed sign) at 0.05 level
Depth (APD)	13.1 ± 2.5	14.4 ± 2.6	0.046
Width (TRD)	17.5 ± 3.3	18.0 ± 3.8	0.176
Area (CSA)	181.5 ± 66.2	203.8 ± 71.7	0.042
N	121	315	

Using CSA as diagnostic criteria, 21% of Group 1 participants had DLSS compared to 14% of Group 2 and the average population prevalence of 16%. The difference was statistically significant with chi square in cross tabulation returning a P value = 0.0028 (Table 3).

Table 3

Prevalence of DLSS

	DLSS absent	DLSS present	Total	(%)
Group 1	95	26	121	21
Group2	271	44	315	14
Total	366	70	436	16
Chi square in cross tabulation				P = 0.0028

There were differences in the prevalence rate within the counties. Kilifi district had the highest prevalence (21%) followed by Taita/Taveta and Kwale 17% and 16% respectively. This was in agreement with the prevalence of ELM in those counties. The differences were however, not statistically significant with chi square in cross tabulation returning a P value = 0.6807 (Table 4). The prevalence was also determined in each county. The prevalence of DLSS in the adult black population of the coast region of Kenya is about 16%.

Table 4

Proportion distribution of DLSS in counties

County	Normal canal	DLSCS	Total	(%)
Kilifi	92	24	116	21
Kwale	39	8	47	16
Mombasa	112	17	129	13
Taita/Taveta	41	9	50	17
Tana River	41	6	47	13
Lamu	40	7	47	14
Total	366	70	436	16
		$\chi 2$	P = 0.6590	

Correlation: The association between ELM and DLSS was further interrogated by running a Pearson product-moment correlation to determine the relationship between ELM and various dimensions of the structure of the lumbar spinal canal (APD and TRD), (Table 5).

Table 5

Correlation of various dimensions of canal size and ELM

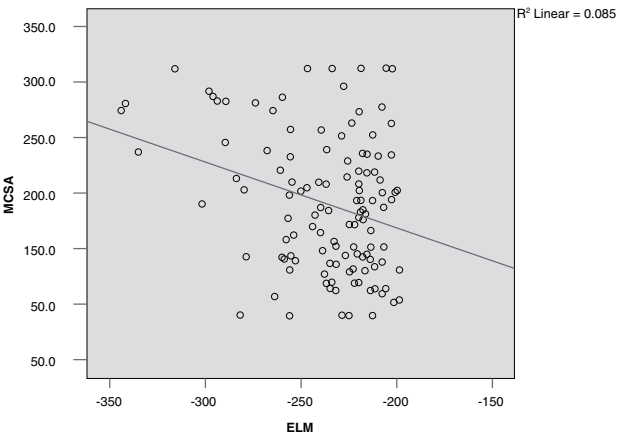
N = 436	Pearson Correlation	Sig. (2-tailed)
APD	-0.678	.033
TRD	-0.497	.020
CSA	-0.648	.022

The result is a significant negative linear correlation between the mean canal depth (APD) 67.8% and cross sectional area (CSA) 64.8%, and a moderate negative linear correlation with the canal width (TRD) of 49.7%.

Regression model: A regression analysis was done to discriminate on the predictor variables and check on how they interact with each other. A regression line was determined on a scatter diagram, (Figure 3).

Figure 3

Regression model



In this model R square (coefficient of determination) is 0.085 which means that the composite variable ELM explains only 8.5% of the variability of the dependent variable, DLSS.

DISCUSSION

The prevalence of ELM in the entire study population was found to be 29%. This is in keeping with the prevalence of stunting in the same population which has been reported to be about 34.7% (11). It is also in keeping with other indicators of malnutrition such as acute PEM reported prevalence of 29.2% (12) and enamel hypoplasia whose ranges were somewhere between 25.1% and 61.2% (13, 14). The distribution of ELM among the six counties reflected the known rainfall patterns with consequent droughts followed by famines. Kilifi County has an ELM prevalence rate of 42% and the urbanized Mombasa County 16%; apart from rainfall, the two counties have overall different poverty levels (15).

There was no gender preponderance in this group with DLSS. Male and female ratio was equal. The mean age for both groups was 43.2 years (P=0.991). In this study the canal dimensions had means of 14mm for depth, 18mm for transverse diameter, and 200mm^2 for cross sectional area. These figures show the population under study to have narrower canals than reported in other populations. Alvarez *et al* (16), reported in a Caucasian population average lumbar spinal canal depth to be 16-20 mm with a mean of 18mm, and the width to be 22–28 (mean = 25mm) yielding a cross sectional area of 276-440mm^2. The prevalence of DLSS was determined in each county and found to have the same pattern as ELM with Kilifi County registering the highest prevalence of 21% and Mombasa County the lowest, 13%. The rest fell in between. The differences within the counties were not however, statistically significant (P=0.680).

The overall prevalence of DLSS in this study is 16%. This is much higher than reported in other studies. Schroeder *et al* (17) reported a prevalence of 9.3% in the American population of lumbar stenosis. Kalichman *et al* (18) in the Framingham study concluded that the prevalence of "congenital stenosis" was 7.3%. Both authors base their conclusions on people of similar ethnic and socio-economic heritage. The higher prevalence in the control group of this study than reported in the literature can be explained by, perhaps, a lack of sharpness of ELM discrimination tool. However, ELM stands out as an important aetiological cause of spinal canal mal-development and DLSS.

This study means of AP mean, 14mm, and TRD mean 18mm and CSA of 200mm^2 represent 78%, 72% and 56% of expected values of reported ideal means for APD, TRD, and CSA respectively. The mean canal depth in Group I was 13.1 ± 2.5 mm against 14.4 ± 2.6 mm in Group 2 (P value 0.046). The mean canal width (transverse diameter) for Group I was 17.5 ± 3.3 mm against 18.0±3.8 in Group 2. (P=0.176). The cross sectional area measurement in those with ELM, was 181.5 ± 66.2 mm against 203.8 ±71.7 mm in Group 2 (P=0.042).

In conclusion, there was a higher frequency of cases of DLSS with association in ELM than without. The mean cross sectional area is significantly reduced in ELM than without. Pearson product-moment correlation had a strong negative linear relationship between ELM and DLSS for all the three measurements; r = -0.68, P= 0.033 (for APD), r = 0.50, P= 0.020 (for TRD), and r = 0.65, p = 0.022 (for CSA). However, a logistic regression model returned a coefficient of determination R^2=0.085 which means a composite variable ELM explains only 8.5% of the variability of DLSS.

Multiple regression from food shortage, childhood sicknesses, country of origin, parental education and occupation and family size statistically significantly predict DLSS, F (127.20.668) =2.655, P<.005, R^2=053.

Compliance with ethical standards

Conflict of interest: The authors declare they have no conflict of interest.

Funding: This study was done using the personal funds of the first author.

Ethical approval: Study approval was given by the Mount Kenya University Ethical Review Board and the licence granted by National Commission for Science, Technology and Innovation (NACOSTI); permit number NACOSTI/P/17/52574/19189.

REFERENCES

1. Manchikanti, L., Singh, V., Falco, F.J., Benyamin, R.M. and Hirsch, J.A. Epidemiology of low back pain in adults. *Neuromodulation: Tech Neural Interface*. 2014; **17**(S2):3-10.
2. Hoy, D., March, L., Brooks, P., Blyth, F., Woolf, A., Bain, C., *et al*. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. *Annals Rheum Dis*. 2014; **73**(6):968-974.

3. Baker, A.D. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *Classic Papers in Orthopaedics: Springer;* 2014. p. 245-247.
4. McCance, R.A. Food, growth, and time. *The Lancet. 1962*; **280**(7257):621-626.
5. De Onis, M. Child growth and development. Nutrition and Health in a Developing World: Springer; 2017. p. 119-141.
6. Adair, L.S. Long-term consequences of nutrition and growth in early childhood and possible preventive interventions. International Nutrition: Achieving Millennium Goals and Beyond: Karger Publishers; 2014. p. 111-120.
7. Parlee, S.D and MacDougald, O.A. Maternal nutrition and risk of obesity in offspring: the Trojan horse of developmental plasticity. Biochimica et Biophysica Acta (BBA). *Molecular Basis Dis*. 2014; **1842**(3):495-506.
8. Arnoldi, C., Brodsky, A., Cauchoix, J., Crock, H., Dommisse, G., Edgar, M., *et al.* Lumbar spinal stenosis and nerve root entrapment syndromes. *Clin Orthop Rel Res*. 1976;**115**:4-5.
9. Ullrich, C.G., Binet, E.F., Sanecki, M.G. and Kieffer, S.A. Quantitative assessment of the lumbar spinal canal by computed tomography. *Radiology*. 1980;**134**(1):137-143.
10. Griffith, J.F., Huang, J., Law, S-W., Xiao, F., Leung, J.C.S., Wang, D., *et al.* Population reference range for developmental lumbar spinal canal size. *Quantitative Imaging Med Surg*. 2016; **6**(6):671.
11. M'Kaibi, F.K., Steyn, N.P., Ochola, S.A. and Du Plessis, L. The relationship between agricultural biodiversity, dietary diversity, household food security, and stunting of children in rural Kenya. *Food Sci Nutr*. 2017;**5**(2):243-254.
12. Ndemwa, M., Wanyua, S., Kaneko, S., Karama, M. and Anselimo, M. Nutritional status and association of demographic characteristics with malnutrition among children less than 24 months in Kwale County, Kenya. *Pan Afr Med J*. 2017; **28**(265): :doi:10.11604/pamj.2017.28.265.12703
13. Naidu, R.S. and Nunn, J.H. Prevalence of enamel developmental defects and relationship with early childhood caries in Trinidad. *J Dentistry for Children*. 2016; **83**(3):108-113.
14. Ibiyemi, O., Zohoori, F.V., Valentine, R.A., Kometa, S. and Maguire, A. Prevalence and extent of enamel defects in the permanent teeth of 8-year-old Nigerian children. *Comm Dent Oral Epidemiol*. 2018; **46**(1):54-62.
15. Gakuru, W.R. and Mathenga, N.M. Poverty, growth, and income distribution in Kenya: A SAM perspective. agris.fao.org 2015.
16. Alvarez, J.A. and Hardy, Jr R.H. Lumbar spine stenosis: a common cause of back and leg pain-includes patient information. *Am Fam Physician*. 1998; **57**(8):1825-34.
17. Schroeder, G.D., Kurd, M.F. and Vaccaro, A.R. Lumbar spinal stenosis: How is it classified? *JAAOS-J Amer Acad Orthopaed Surg*. 2016; **24**(12):843-852.
18. Kalichman, L., Cole, R., Kim, D.H., Li, L., Suri, P., Guermazi, A., *et al.* Spinal stenosis prevalence and association with symptoms: the Framingham Study. *The Spine J*. 2009; **9**(7):545-550.