UNIVERSITI PUTRA MALAYSIA

MATERNAL AND NEONATAL VITAMIN D DEFICIENCY, VITAMIN D-RELATED GENE POLYMORPHISM AND BIRTH OUTCOMES

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Philosophy

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MATERNAL AND NEONATAL VITAMIN D DEFICIENCY, VITAMIN D-RELATED GENE POLYMORPHISM AND BIRTH OUTCOMES

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December 2019

Chair : Assoc. Prof. Loh Su Peng, PhD
Faculty : Medicine and Health Sciences

Epidemiology data have shown widespread vitamin D deficiency in several populations. However, up to date, data on vitamin D status of women and neonates living in Malaysia is scarce to inform the development of national recommendation for vitamin D supplementation for pregnant women and newborns. In addition, the associations between low maternal and cord 25-hydroxyvitamin D (25OHD) with size at birth is inconsistent, and the plausible mechanisms of action of vitamin D on fetal growth have remained unexplored. Therefore, this study aims to determine the prevalence of vitamin D deficiency in pregnant women and newborns at delivery as well as factors associated with the deficiency. At the same time, this study also sought to investigate the associations between maternal and cord total vitamin D deficiency, and vitamin D polymorphism with birth outcomes concomitantly.

Healthy pregnant women and neonates (217 dyads) were recruited from Hospital Serdang, Selangor, Malaysia. Venous blood was collected from pregnant mothers before delivery. Umbilical cord blood was collected from the severed umbilical cord after the delivery of the baby but before the delivery of the placenta. Maternal and cord total 25OHD levels were measured by using a validated ultra-high-performance liquid chromatography (UHPLC) method. Vitamin D Receptor (*VDR)* polymorphism (rs2228570) was determined using High-Resolution Melting (HRM), while Group-Specific component (*GC)* polymorphisms (rs4588 and rs7041) were determined using restriction fragment length polymorphism (RFLP).

The result showed that the median maternal total 25OHD was 29.8 nmol/L (Interquartile Range [IQR] 18.8-43.5 nmol/L), with 50.2% of pregnant women had vitamin D deficiency (25OHD <30 nmol/L). Multivariate analysis showed that the risk factors of maternal vitamin D deficiency (25OHD <30nmol/L) were age, veiled clothing, homozygous mutant for *GC* rs7041. On the other hands, the protective factors for maternal vitamin D deficiency were vitamin D intake from food and supplements.

The median cord total 25OHD was 22.0 nmol/L (IQR 15.5-31.0 nmol/L), which 71.4% of newborns had vitamin D deficiency (25OHD <30 nmol/L). Consistent with the previous studies, maternal status was the best predictor of neonatal vitamin D deficiency (25OHD < 30nmol/L). In the present study, neonates born from a mother with vitamin D deficiency had eight times higher risk of deficiency. Moreover, factors that independently associated with neonatal vitamin D deficiency were nulliparous, vitamin D supplements, maternal vitamin D binding protein level, and maternal *VDR* rs2228570.

In addition, the analysis showed that maternal but not cord vitamin D deficiency was inversely associated with birth weight, head circumference, and length at birth. In contrast, cord but not maternal *VDR* rs2228570 was significantly associated with birth weight. Additionally, cord but not maternal *GC* rs4588 was significantly associated with the head circumference. A potential interaction effect between maternal *VDR* rs2228570 SNP and maternal vitamin D deficiency on head circumference was observed.

In conclusion, a high prevalence of maternal and cord vitamin D deficiency was observed in this study. The analysis of factors associated with vitamin D deficiency supports supplementation as a potential strategy to decrease the risk of deficiency. The current work also consistently showed that maternal but not cord vitamin D deficiency was associated with the birth outcomes. In contrast, cord but not maternal SNPs were associated with several of the birth outcomes.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KEKURANGAN VITAMIN D, POLIMORFISME GEN BERKAITAN DENGAN VITAMIN D DALAM KALANGAN WANITA HAMIL DAN NEONAT SERTA HASIL KELAHIRAN

Oleh

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Data epidemiologi menunjukkan masalah kekurangan vitamin D yang berleluasa dalam beberapa populasi. Walau bagaimanapun, setakat ini data mengenai status vitamin D bagi wanita hamil dan bayi yang baru lahir di Malaysia adalah tidak mencukupi untuk memberi saranan pengambilan suplemen vitamin D untuk ibu hamil dan bayi yang baru lahir. Selain itu, hubungan antara paras 25OHD ibu dan bayi dengan saiz bayi semasa kelahiran adalah tidak konsisten dan mekanisme vitamin D terhadap pertumbuhan janin masih belum diketahui. Oleh itu, kajian ini bertujuan untuk menentukan kelaziman kekurangan vitamin D dalam kalangan wanita hamil dan bayi yang baru lahir dan faktor-faktor yang berhubung kait dengan kekurangan tersebut. Pada masa yang sama, kajian ini juga bertujuan untuk menyiasat hubungan antara kekurangan vitamin D dan polimorfisme vitamin D dalam kalangan wanita hamil dan bayi dengan hasil kelahiran.

Pasangan wanita hamil dan bayi yang sihat (217 pasang) dari Hospital Serdang, Selangor, Malaysia telah direkrut untuk menyertai kajian ini. Darah venus diambil dari wanita hamil sebelum bersalin. Darah tali pusat diambil dari tali pusat selepas kelahiran bayi, tetapi sebelum uri dikeluarkan. Paras *25-hydroxyvitamin D* (25OHD) dari darah ibu dan darah tali-pusat telah diukur dengan menggunakan kaedah *ultra-high-performance liquid chromatography (UHPLC*) yang telah disahkan. Polimorfisme *Vitamin D Receptor (VDR)* (rs2228570) ditentukan dengan mengunakan *High-Resolution Melting* (HRM), manakala polimorfisme *Group Specific Component (GC)* (rs4588 dan rs7041) ditentukan dengan menggunakan *restriction fragment length polymorphism* (RFLP).

Hasil kajian menunjukkan bahawa median 25OHD bagi wanita hamil adalah 29.8 nmol/L (IQR 18.8-43.5 nmol/L) di mana 50.2% wanita hamil kekurangan vitamin D (25OHD <30 nmol/L). Analisis multivariat menunjukkan bahawa faktor-faktor risiko kekurangan vitamin D (25OHD < 30nmol/L) di kalangan ibu hamil adalah umur,

berhijab, mutan homozigus untuk polimorfisme rs7041. Manakala faktor perlindungan untuk kekurangan vitamin D wanita hamil adalah pengambilan vitamin D dari pemakanan dan suplemen.

Median 25OHD bagi bayi yang baru lahir adalah 22.0 nmol/L (IQR 15.5-31.0 nmol/L) di mana 71.4% bayi kekurangan vitamin D (25OHD <30 nmol/L). Selaras dengan kajian terdahulu, status ibu adalah peramal terbaik kekurangan vitamin D (25OHD <30 nmol/L) di kalangan bayi yang baru lahir. Berdasarkan kajian ini, bayi yang dilahirkan oleh ibu yang kekurangan vitamin D berisiko 8 kali lebih tinggi kekurangan vitamin D. Selain itu, faktor-faktor yang berkait secara signfikan dengan kekurangan vitamin D di kalangan bayi adalah pengambilan vitamin D dari suplemen, tahap *vitamin D binding protein (VDBP)* ibu dan polimorfism *VDR* rs2228570 ibu.

Analisis menunjukkan bahawa kekurangan vitamin D di kalangan ibu berkait secara songsang dengan berat kelahiran, lilitan kepala dan panjang semasa kelahiran. Sebaliknya, *VDR* rs2228570 bayi berkait secara signifikan dengan berat lahir. Di samping itu, *GC* rs4588 bayi berkait secara signifikan dengan lilitan kepala. Sebaliknya, terdapat potensi hubungan interaksi antara *VDR* rs2228570 SNP ibu dan kekurangan vitamin D ibu pada lilitan kepala bayi.

Kesimpulannya, didapati bahawa kadar kelaziman kekurangan vitamin D adalah tinggi di kalangan wanita hamil dan bayi yang baru lahir dalam kajian ini. Analisis faktor-faktor berkait dengan kekurangan vitamin D menyokong pemberian suplemen sebagai strategi yang berpotensi untuk mengurangkan risiko kekurangan vitamin D. Kajian ini juga konsisten dalam menunjukkan bahawa kekurangan vitamin D di kalangan ibu mempunyai kaitan dengan hasil kelahiran. Sebaliknya, polimorfisme bayi berkait secara signifikan dengan beberapa hasil kelahiran.

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LIST OF ABBREVIATIONS

%BSA	Percent of body surface area
$1,24,25(OH)_3D$	1,24,25-trihydroxyvitamiN D
$1,25(OH)_2D$	1,25-dihydroxyvitamin D
24-hydroxylase	25-hydroxyvitamin D-24-hydroxylase
$24,25(OH)_2D$	24,25-dihydroxyvitamin D
25OHD	25-hydroxyvitamin D
AI	Adequate intake
AR	Average Requirement
BMI	Body Mass Index
BSA	Bovine serum albumin
BSAP	Bone-specific alkaline phosphatase
CBPAs	Competitive protein-binding assays
CDC	Centers for Disease Control and Prevention
CLIAs	chemiluminescent immunoassays
CV	Coefficient of variation
CYP24A1	25-hydroxyvitamin D-24-hydroxylase
DAD	Diode Array Detector
DNA	Deoxyribonucleic acid
DRI	Dietary Reference Intakes
DRV	Dietary Reference values
EAR	Estimated Average Requirement
EDD	Estimated due date
EFSA	European Food Safety Authority
EFSA NDA Panel	EFSA Panel on Dietetic Products, Nutrition, and Allergies
ELISAs	enzyme-linked immunoassays
ESTF	Endocrine Society task force
FAO	Food and Agriculture Organisation
FDA	Food and Drug Administration
FFQ	Food Frequency Questionnaire
FGF23	Fibroblast-like growth factor-23
FNRI-DOST	The Food and Nutrition Research Institute of the Department of Science and Technology (Philippine)
GC	Group-specific component of serum
GLM	General linear model
GRS	Genetic Risk Scores
GRCh38.p7	Genome Reference Consortium Human Build 38 patch release 7
GWAS	Genome-wide association studies
GWG	Gestational weight gain
HRM	High Resolution Melting
HPB	Health Promotion Board Singapore
HWE	Hardy-Weinberg Equilibrium
IGF-1	Insulin-like growth factor type I
ILSI-SEA	International Life Sciences Institute, South East Asia Region
IOM	Institute of Medicine

iPTH	Intact parathyroid hormone
IQR	Interquartile range
IS	Internal standard
LC	Liquid-chromatographic
LLE	Liquid-liquid extraction
LMP	Last menstrual period
LOD	Limit of detection
LOQ	Limit of quantification
MAF	Minor allele frequency
MCNV	Ministry of Health Vietnam
MHLW	Ministry of Health, Labour and Welfare (Japan)
MOH-RI	Ministry of Health, Republic of Indonesia
NaOH	Sodium Hydroxide
NHMRC	National Health and Medical Research Council
NORDEN	Nordic Council of Ministers
NZ MOH	New Zealand Ministry of Health
PAC	Patient Assessment Center
PBS	Phosphate buffered saline
PCR	Polymerase Chain Reaction
PRI	Population Reference Intake
PTH	Parathyroid hormone
PTHrP	Parathyroid hormone-related protein
RDA	Recommended Dietary Allowance
RFLP	Restriction fragment length polymorphism
RI	Recommended intake
RIAs	Radio-immunoassays
RMPs	Reference Measurement Procedures
RNI	Recommended Nutrient Intakes
ROC	Receiver operating characteristic
RXR	Retinoid X receptor
SACN	Scientific Advisory Committee on Nutrition
SD	Standard deviation
SGA	Small for gestational age
SNP	Single Nucleotide Polymorphism
SPE	Solid Phase extraction
SPSS	Statistical package for the social science
TL	Tolerable upper intake level
UHPLC	Ultra-high-performance liquid chromatography
UK	United Kingdom
US	United States
USDA	United States Department of Agriculture
UV	Ultraviolet
UVR	Ultraviolet radiation
VDBP	Vitamin D binding protein
VDR	Vitamin D Receptor
VDRE	Vitamin D response element
WHO	World Health Organisation

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CHAPTER 1

INTRODUCTION

1.1 Background

Vitamin D plays an important role in regulating bone metabolism by stimulating the intestinal absorption of calcium and phosphorus. Severe vitamin D deficiency causes rickets in children and osteomalacia in adults (Holick, 2007). Besides, this long-standing role in bone metabolism, vitamin D has become increasingly recognised for its role in the pathophysiology of various non-skeletal health outcomes. The non-skeletal outcomes that have been suggested to associate with vitamin D include diabetes (Boucher, 2011), cancer (Moukayed & Grant, 2017), cardiovascular disease (Reddy Vanga, Good, Howard, & Vacek, 2010), and some autoimmune disease (Chen, He, Shoenfeld, & Zeng, 2019).

The emergence of evidence on the non-skeletal role for vitamin D has come together with the appreciation that vitamin D deficiency may be widespread (Holick, 2007). Vitamin D deficiency among pregnant women has particularly gained attention. Pregnancy is a stage of tremendous change in physiology and increased in nutrients requirement to support the rapid growth of the fetus. Within the paradigm of developmental origins of health and disease, the intrauterine environment plays an important role in programming the risk of disease later in life (Barker, 1998; Godfrey & Barker, 2007). Poor fetal intrauterine nutrition environment will lead to poor fetal growth and development and subsequently results in poor neonatal anthropometry at birth. All these events have been shown to increase perinatal morbidity and the risk of metabolic syndrome later in life (Cho & Suh, 2016; Roth & DiVall, 2016; Whincup et al., 2008).

Previous observational studies in United States of America (Chawla et al., 2019), Canada (Li et al., 2011; Woolcott et al., 2016), the United Kingdom (Gale et al., 2008; Yu, Ertl, Samaha, Akolekar, & Nicolaides, 2011) Netherlands (Vinkhuyzen et al., 2016), and Australia (Bowyer et al., 2009; Schneuer et al., 2014) have consistently reported a high prevalence of vitamin D deficiency in pregnant women. It is expected that vitamin D deficiency would be high in the population in northern countries which have limited sunlight. However, a high prevalence of vitamin D deficiency has been reported in Iran (Maghbooli et al., 2007), India (Sahu et al., 2009), Bangladesh (Islam, Akhtaruzzaman, & Lamberg-Allardt, 2006) despite abundant access to sunshine in these areas throughout the year. More recently, studies in Vietnam, Thailand, and Indonesia also showed widespread of VDD in women (Chailurkit, Aekplakorn, & Ongphiphadhanakul, 2011; Green et al., 2008; Laillou et al., 2013).

In humans, the primary source of vitamin D is synthesised in the skin after exposure to ultraviolet rays of sunlight; the diet is a secondary source of vitamin D (Holick, 2007). A combination of a change in lifestyle (with more daylight hours spent indoors), liberal use of sunscreens (in some parts of the world, mostly driven by concerns about the risk of skin cancer), adoption of covered attire (consistent with the accepted cultural norms in some societies), and global environmental pollution might have contributed to the widespread increase in vitamin D deficiency(Hossein-nezhad & Holick, 2013).

After birth, infants depend on their vitamin D stores at birth and dietary intake for the supply of vitamin D (Wagner, Taylor, Johnson, & Hollis, 2012). Due to breastmilk is low in vitamin D content (Jan Mohamed, Rowan, Fong, & Loy, 2014), breastfed infants have to depend on their vitamin D stores at birth for their supply of vitamin D. Infants of vitamin D replete mothers will have sufficient vitamin D stores at birth for their first 3-4 months of their life (Di Marco, Kaufman, & Rodda, 2019). Given the widespread of maternal vitamin D deficiency, infants may be born with low vitamin D stores. With the concern of re-emergence of rickets, national vitamin D supplementation recommendations for pregnant and infants have been implemented in the countries at northern latitudes. Nonetheless, there is no existing national policy or recommendation for vitamin D supplementation for pregnant and infants in other countries like Malaysia.

1.2 Problem statements

In Malaysia, vitamin D deficiency have been reported to affect children (Khor et al., 2011), adult (Moy & Bulgiba, 2011), women at childbearing age (Green et al., 2008) and postmenopausal women (Rahman, Chee, Yassin, & Chan, 2004) residing in Kuala Lumpur city. Jan Mohamed et al. (2014) had reported 59.8% and 37.3% of vitamin D deficiency (25OHD <50nmol/l) in Kelantan pregnant women in the second and third trimester, respectively. This study, however, was only included Malay pregnant women within a particular region with specific local ethnic practice (Jan Mohamed et al., 2014). Data on the prevalence of VDD in pregnant mother of major ethnic groups (Malay, Chinese and Indian) in Klang valley area is scarce.

Previously, factors including latitude, sun exposure, skin type, clothing, dietary vitamin D intake, Body Mass Index (BMI), ethnicity, and genetic, have been identified to associate with maternal vitamin D deficiency (Hossein-nezhad & Holick, 2013). However, the associations of these factors with maternal vitamin deficiency vary from studies to studies. This discrepancy suggests that vitamin D status is country-, ethnic- and subgroup-specific. For instances, previous studies of vitamin D in pregnant mother by Jan Mohamed et al., (2014) did not measure the influence of sun exposure and skin type on serum 25(OH)D concentration. Likewise, different lifestyle in Klang valley area or changing in lifestyle in pregnant women may put pregnant women at risk of vitamin D deficiency. Therefore, this study includes sun exposure (clothing, time spent outdoor) and skin type as part of variables that potentially associated with 25(OH)D concentration. Likewise, only a small number of studies have comprehensively examined the factors, notably environmental and genetic factors in parallel, with maternal vitamin D deficiency. These studies were mostly conducted among the Caucasian population. There were limited data on environmental and genetic determinants of 25OHD in pregnant women in the Southeast Asian region.

Despite the importance of vitamin D to fetus and infants, less attention has been paid to investigate the prevalence and the factors associated with vitamin D deficiency in cord blood or neonates. Previous cord blood studies have been limited by small sample size. Although some large sample size studies have examined a wide range of factors associated with neonatal vitamin D, maternal vitamin D was not accounted for. As maternal and cord vitamin D status is closely related, maternal 25OHD may be a confounder for the factors found to significantly associated with cord vitamin D. Moreover, no previous study has investigated vitamin D status in the newborn (cord) in Malaysia.

With respect to the impact of vitamin D deficiency, there is a growing number of studies investigating the associations between maternal and neonatal vitamin D deficiency with birth outcomes, but the evidence was inconsistent. Maternal and neonatal vitamin D deficiency have been shown to be associated with poor birth outcomes in some observational studies, but not in other studies (Tous, Villalobos, Iglesias, Fernández-Barrés, & Arija, 2020). Similarly, the evidence of maternal vitamin D on birth outcomes from intervention studies was abundant but was inconsistent (Roth et al., 2017).

Besides the heterogeneity between previous studies, it has been suggested that the inconsistency may be due to the interaction effect of single nucleotide polymorphisms (SNPs) with 25OHD (Chun, Shin, Kim, Joung, & Chung, 2017; Morley, Carlin, Pasco, Wark, & Ponsonby, 2009). However, the interaction effects have been addressed in very few studies. Moreover, the inconsistency could be due to free or bioavailable 25OHD, which are believed to be more physiologically active, but not total 25OHD is associated with birth outcomes. There is only one study investigating the associations of maternal total and bioavailable 25OHD on birth weight (Gustafsson et al., 2018).

1.3 Significance of the study

This study provides the data on the prevalence of vitamin D deficiency among pregnant mothers and their neonates residing in Klang Valley. This data has public health implication, which can suggest the need for a formal recommendation for vitamin D supplementation for pregnant women and infants. In addition, this study takes a comprehensive approach to assess the contribution of a wide range of factors that potentially associated with vitamin D deficiency. This data is very important in identifying the group at risk of deficiency and informing the potential intervention. Besides, it can be used as a reference for planning the intervention for the prevention of vitamin D deficiency among pregnant women and neonates. Besides exogenous factors, this study investigates the correlation of various vitamin D metabolites in mothers' blood and cord blood, which the finding may provide the insight of maternal-fetal transfer of vitamin D.

It has been known that the factors contributed to fetal growth and birth outcomes are certainly more complex than to be explained entirely by variation in vitamin D status and SNPs. However, concomitant showed in the analysis the associations between maternal and cord vitamin D deficiency and selected vitamin D SNPs with birth outcomes could potentially unravel the plausible mechanism underlying the association of vitamin D and fetal growth. The exploration of the association of bioavailable 25OHD and birth outcomes may explain the inconsistency of the previous associations of vitamin D and birth outcomes. Likewise, the investigation of interaction effects between SNPs and vitamin D on birth outcomes can contribute to this growing area of research by understanding the interplay between genetics, vitamin D and birth outcomes.

1.4 Objectives

This thesis aims to investigate maternal and umbilical cord blood vitamin D deficiency and functional vitamin D and the associations with birth outcomes. The specific objectives of this thesis are:

1. To assess maternal and cord
   a) vitamin D status
   b) distribution of *GC* and vitamin D receptor (*VDR*) gene SNPs (rs4588, rs7041, rs2228570)
2. To determine genetic, dietary, and lifestyle factors associated with maternal and cord vitamin D status
3. To determine the associations between maternal vitamin D deficiency, maternal bioavailable 25OHD, maternal *VDR*, and *GC* SNPs, cord vitamin D deficiency, and cord *VDR* and *GC* SNPs on birth outcomes
4. To identify potential interactions between vitamin D deficiency with *VDR* and *GC* SNPs with birth outcomes.

1.5 Thesis outlines

The overall structure of this thesis takes the form of six chapters. Following the introduction, statement of problem, and objectives in **Chapter 1**, **Chapter 2** presents the summary of existing literature, which conceptualises the aims of current thesis. It begins by providing the background of vitamin D, and then review the vitamin D deficiency in pregnant women and neonates, details on dietary vitamin D and vitamin D polymorphism. Finally, the chapter discusses existing evidence of vitamin D on birth outcomes. Each of the section in this literature review is ended with a summary and critique, which lead to the development of the objectives of this thesis.

The **third chapter** describes the study methods, which the first two sections describe the data collection and assessment of variables of interest in the field. The subsequent two parts described the laboratory procedure for biochemical analysis and genotyping. The final sections outline data management and data analysis.

Chapter 4 presents the findings of the research, while **Chapter 5** discusses the findings of the study. In overall, these two chapters are divided into five major sections, which included 1) method development and validation 2) description of variables of interest 3) maternal vitamin D deficiency 4) umbilical cord vitamin D deficiency 5) associations of vitamin D deficiency and SNPs with birth outcomes. There is an additional section in chapter 5 that discusses the implication of the present work.

The final chapter, **Chapter 6,** concludes the findings of the study, outlines the strength and limitation of the study and presents the recommendations for future research direction.

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BIODATA OF STUDENT

Lee Siew Siew qualifies as a nutritionist with her first degree in Bachelor of Science (Nutrition and Community Health) in Universiti Putra Malaysia. She was then sponsored by Ministry of Higher Education Malaysia through Mybrain Myphd scholarship to further her PhD degree in Universiti Putra Malaysia. Up to date, she had presented poster and paper at three local and three international conferences, respectively. Her research interests are in the area of maternal and child nutrition, vitamin D, polymorphism and Developmental Origins of Health and Disease (DOHaD).

LIST OF PUBLICATIONS

Lee, S.S., Loh, S.P., Subramaniam, R., Tusimin, M., Ling, K.H., & Rahim, K.F. (2020). Association of maternal and cord plasma total, free and bioavailable 25-hydroxyvitamin D with neonatal anthropometric measurements at birth: A preliminary study in a private hospital. *Malaysian Journal of Medicine & Health Sciences*,*16*(1), 24-31.

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Oral presentations

Lee, S.S., Loh, S.P., Subramaniam, R., Tusimin, M., Ling, K.H., Rahim, F.K. (2019). Vitamin D deficiency and its related factors in umbilical cord blood of neonates. 3-4 July 2019. 34th NSM Annual Scientific Conference. Hotel Istana, Kuala Lumpur, Malaysia.

Lee, S.S., Loh, S.P., Subramaniam, R., Tusimin, M., Ling, K.H., Rahim, F.K. (2019). Vitamin D deficiency and its associated factors in healthy Malaysian pregnant women. 1-5th December 2019. The 7th International Conference of Food Factors. Kobe Convention Center, Kobe, Japan.

Poster presentations

Lee, S.S. & Loh, S.P. (2014). Vitamin D status and its associated factors in healthy pregnant mothers and their newborns. 3-4 June 2014. 29th NSM Annual Scientific Conference. Renaissance Hotel, Kuala Lumpur, Malaysia,

Lee, S.S., Loh, S.P., & Subramaniam, R. (2015). Vitamin D status and its associated factors in healthy pregnant mothers and their newborns in Malaysia- A preliminary study. 23-25 November 2015. The 6th International Conference on Food Factors. COEX, Seoul, Korea.

Lee, S.S., Loh, S.P., Subramaniam, R., Tusimin, M., Ling, K.H., Rahim, F.K. (2019). Higher prevalence of term small for gestational age (SGA) than term low birth weight (LBW). 5 July 2019. 1st Scientific Seminar on Body Composition and Nutrition. Hospital Universiti Putra Malaysia, Serdang, Malaysia.

Lee, S.S., Loh, S.P., Ling, K.H., Tusimin, M., Rahim, F.K., Subramaniam, R. (2019). Interplay between Maternal and Cord Vitamin D status and Vitamin D Receptor Polymorphism in Infant Birth Weight. 20th-23rd October 2019. International DOHaD 2019 Congress, Melbourne Convention and Exhibition Centre, Melbourne, Australia.

Award received

1. Poster Award. Vitamin D status and its associated factors in healthy pregnant mothers and their newborns in Malaysia- A preliminary study. The 6th International Conference on Food Factors, COEX, Seoul, Republic of Korea.

2. Travel Award for LMIC. Interplay between Maternal and Cord Vitamin D status and Vitamin D Receptor Polymorphism in Infant Birth Weight. The International DOHaD 2019 Congress, Melbourne Convention and Exhibition Centre, Melbourne, Australia.

3. Young Investigator Award. Vitamin D deficiency and its associated factors in healthy Malaysian pregnant women. The 7th International Conference of Food Factors. Kobe Convention Center, Kobe, Japan.

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