UNIVERSITI PUTRA MALAYSIA

FOOD INSECURITY AND VITAMIN D DEFICIENCY FACTORS, AND EFFECTS OF VITAMIN D SUPPLEMENTATION ON METABOLIC SYNDROME AMONG FOOD INSECURE AND VITAMIN D DEFICIENT IRANIAN ELDERLY

MARYAM ZAREI

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By

MARYAM ZAREI

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

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DEDICATION

***To the God**, for helping me in every step of this journey and giving me the strength to continue until the end. I would not have finished this course without the favour, grace, love, and wisdom of God.*

***To** prophet Muhammad and Ahlol Bayt*

***To** the memory of my martyred father to whom I am much indebted,*

***To** my loving mother,*

***To** my hero, Prof. Dr. Ebrahim Khalil Naderali*

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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Chairman : Geeta Appannah, PhD
Faculty : Medicine and Health Sciences

In almost every country, elderly population is growing faster than any other age groups with its age-related lifestyle changes, physical disabilities potentially chronic disease ultimately forcing them to remain indoors. The above factors may directly affect their ability to have access to food as well as potentially being impacted by food insecurity. Food insecurity can contribute to poor health and nutrition deficiency of which vitamin D deficiency is the most common one seen in older adults. Although there are numerous studies have been conducted on the effects of vitamin D supplementation in adults, but little or no data has been reported on the effects of vitamin D supplementation in older adults with vitamin D deficiency, especially amongst Iranian older adults. This study comprised of two phases; the first phase was a cross-sectional, conducted to determine the prevalence and factors associated with food insecurity and vitamin D deficiency among older adults in Karaj city, Iran. Study subjects were recruited based on a defined set of inclusion criteria *via* systematic random sampling. An interviewer-administered questionnaire was used to capture information on socioeconomic characteristics, medical history, and food security status, sun exposure and food frequency questionnaire (FFQ). Anthropometric measurements including weight, height and waist circumference as well as blood pressure were measured by trained research staff directly after the interview. Fasting blood samples were collected for quantifying serum 25-hydroxyvitamin D [25(OH) D] level. Adjusted logistic regression was used to identify associations between food insecurity, vitamin D deficiency and selected predictor variables. The second phase of this study was a randomized control trial (RCT) to examine the effects of vitamin D supplementation on metabolic syndrome parameters such as [body mass index (BMI), waist circumference (WC), blood pressure (BP), total cholesterol (TC), triglyceride (TG), low-density lipoprotein (LDL-C), high-density lipoprotein (HDL-C), fasting blood sugar (FBS)], and as well as 25(OH)D concentration among food insecure and vitamin

D deficient older adults, before and after 2 months supplementation with vitamin D in Karaj city, Iran. Out of 422 subjects from phase I, a total of 120 food insecure subjects were enrolled into phase 2 of the study. Food insecure subjects were vitamin D deficient (< 30 ng/ml), and with at least one metabolic syndrome parameters (from self-reported medical history) were included to phase two *via* simple allocation randomisation. The subjects (60 intervention and 60 placebo) were assigned to receive either weekly vitamin D supplement (intervention group: 50,000 IU 25(OH) D3) or a placebo capsule (placebo group) for two months. Fasting blood samples were collected for quantifying serum 25(OH) D level, FBS and lipid profile at baseline and after completing two months treatment. Anthropometric characteristics, blood pressure (BP) and blood collection were monitored by using analysis of covariance at baseline and after intervention. Result from phase one showed that 31.7% older adults were food insecure while 60.4% were vitamin D deficient with a higher rate among the females. Logistic regression analysis indicated that a minimum household income of 800,000 T (160 $USD), and having more than three metabolic syndrome parameters significantly increased the odds of food insecurity by almost 16-fold (AOR = 16.27, 95% CI = 8.09 - 30.28) and 5-fold (AOR = 4.615, 95% CI = 2.654 - 8.877), respectively. Obese respondents had significantly higher odds (AOR = 3.105, 95% CI = 1.933 - 4.987) of food insecurity by almost three-fold. Food insecure older adults were more likely to consume high energy (AOR = 1.477, 95% CI = 1.139 - 1.944), and carbohydrate (AOR = 1.710, 95% CI = 1.112 - 2.631) intakes compared to food secure older adults. Food insecure older adults were also more likely to be vitamin D deficient (AOR = 1.472, 95% CI = 0.953 - 2.273). In addition, being a female increased odds of vitamin D deficiency by two-fold (AOR = 1.810; 95% CI = 1.181-2.772), whilst obesity increased odds of vitamin D deficiency by almost five-fold (AOR = 4.703; 95% CI = 2.312 - 9.566). In phase two of the study, supplementation of vitamin D3 for two months improved mean change of FBS, TG, TC, LDL-C and systolic BP (p = 0.004, p = 0.001, p = 0.001, p = 0.003, p = 0.001, respectively), and resulted in a significant improvement of mean serum 25(OH) D concentration in the intervention group compared to the control group (p = 0.001). No significant differences were observed when comparing body weight status, WC, diastolic BP and HDL-C between intervention and control groups at baseline and after intervention. In summary, this study indicated that a significant level of food insecurity is present in older adults in Iran which was associated with socioeconomic factors, dwelling arrangements. This in turn affected prevalence of chronic diseases such as vitamin D deficiencies and decreased health-related quality of life in older adults. Vitamin D deficiency had detrimental effects on health in older adults while vitamin D supplementation improves vitamin D status and a number of risk factors for cardiovascular disease. Therefore, replenishing vitamin D levels in older adults could reduce premature morbidity and mortality in food insecure older adults.

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

FAKTOR-FAKTOR KEKURANGAN VITAMIN D DAN KETAKJAMINAN MAKANAN DAN KESAN-KESAN PENAMBAHAN VITAMIN D TERHADAP SINDOM METABOLIK DALAM KALANGAN WARGA TUA KURANG VITAMIN D DAN TIDAK TERJAMIN MAKANAN IRAN

Oleh

MARYAM ZAREI

Mei 2019

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Hampir di setiap negara, populasi warga tua berkembang lebih cepat daripada mana-mana kumpulan usia yang lain dan dengan perubahan gaya hidup berkaitan usia, kecacatan fizikal yang berpunca daripada penyakit kronik berpotensi memaksa mereka kekal di dalam rumah. Faktor-faktor di atas boleh secara langsung menjejaskan keupayaan mereka untuk mempunyai akses kepada makanan, serta berpotensi mengalami kesan ketidakjaminan makanan. Ketidakjaminan makanan boleh menyumbang kepada kesihatan yang tidak baik dan kekurangan pemakanan, di mana kekurangan vitamin D adalah yang paling lazim di kalangan warga tua. Walaupun terdapat banyak kajian yang telah dijalankan berkaitan dengan kesan-kesan suplementasi vitamin D di kalangan orang dewasa, namun sedikit atau tiada data yang melaporkan mengenai kesan suplementasi vitamin D di kalangan warga tua yang kekurangan vitamin D, terutamanya di kalangan warga tua Iran. Kajian ini terdiri daripada dua fasa; fasa pertama adalah kajian hirisan lintang yang dijalankan untuk menentukan prevalens dan faktor-faktor berkaitan ketidakjaminan makanan dan kekurangan vitamin D di kalangan warga tua di kota Karaj, Iran. Subjek kajian didapati berdasarkan kriteria pemilihan yang ditetapkan menerusi persampelan rawak sistematik. Soal selidik kendalian penyelidik telah digunakan untuk mendapatkan maklumat mengenai ciri-ciri sosioekonomi, sejarah perubatan, status sekuriti makanan, pendedahan cahaya matahari dan soal-selidik kekerapan makanan (FFQ). Ukuran antropometri termasuk berat badan, ketinggian dan ukurlilit pinggang, serta tekanan darah telah diukur oleh penyelidik terlatih sejurus selepas sesi soal-selidik. Sampel darah berpuasa dikumpulkan untuk menentukan paras serum 25-hydroxyvitamin D [25(OH)D]. Logistik regresi terlaras (a*djusted logistic regression)* digunakan untuk mengenalpasti perkaitan antara ketidakjaminan makanan, kekurangan vitamin D dan variabel prediktor yang terpilih. Fasa kedua kajian ini adalah percubaan terkawal secara rawak (RCT) untuk mengkaji kesan suplementasi

vitamin D ke atas parameter-parameter sindrom metabolik seperti indeks jisim tubuh (BMI), ukutlilit pinggang (WC), tekanan darah (BP), jumlah kolesterol (TC), trigliserida (TG), lipoprotein berketumpatan rendah (LDL-C), lipoprotein berketumpatan tinggi (HDL-C), gula darah berpuasa (FBS), serta kepekatan 25(OH)D di kalangan warga tua yang kekurangan vitamin D, sebelum dan selepas 2 bulan suplementasi vitamin D di bandar Karaj, Iran. Daripada 422 orang subjek dari fasa I, seramai 120 subjek yang mempunyai sekuriti makanan telah didaftarkan ke dalam fasa 2 kajian. Subjek yang mengalami ketidakjaminan makanan dengan kekurangan vitamin D (<30 ng/ml), dan yang mempunyai sekurang-kurangnya satu parameter sindrom metabolik (dari sejarah perubatan laporan kendiri) didaftarkan ke dalam fasa 2 melalui peruntukan rawak mudah (*simple allocation randomisation*). Subjek (60 intervensi dan 60 plasebo) diperuntukkan untuk sama ada menerima suplemen vitamin D mingguan (kumpulan intervensi: 50,000 IU 25(OH) D3) ataupun kapsul plasebo (kumpulan plasebo) selama dua bulan. Sampel darah berpuasa dikumpulkan untuk menentukan para's serum 25(OH) D, FBS dan profil lipid pada *baseline* dan selepas selesainya rawatan dua bulan. Ciri-ciri antropometrik, tekanan darah (BP) dan pengumpulan darah dipantau dengan menggunakan analisis kovarians pada *baseline* dan selepas intervensi. Hasil kajian dari fasa pertama menunjukkan bahawa 31.7% warga tua mengalami ketidakjaminan makanan, manakala 60.4% kekurangan vitamin D dengan kadar yang lebih tinggi di kalangan wanita. Analisis regresi logistik (*logistic regression analysis)* menunjukkan bahawa pendapatan isi rumah minimum 800,000 T (160$USD), dan mempunyai lebih daripada tiga parameter sindrom metabolik masing-masing secara signifikannya meningkatkan kemungkinan ketidakjaminan makanan hampir sebanyak 16 kali ganda (AOR = 16.27, 95% CI = 8.09 - 30.28) dan 5 kali ganda (AOR = 4.615, 95% CI = 2.654 - 8.877). Responden yang obes secara signifikannya mempunyai kemungkinan yang lebih tinggi (AOR = 3.105, 95% CI = 1.933 - 4.987) untuk mengalami ketidakjaminan makanan hampir sebanyak tiga kali ganda. Warga tua yang mengalami ketidakjaminan makanan lebin cenderung mengambil makanan yang tinggi tenaga (AOR = 1.477, 95% CI = 1.139 - 1.944), dan karbohidrat (AOR = 1.710, 95% CI = 1.112 - 2.631) berbanding warga tua yang mempunyai sekuriti makanan. Warga tua yang mempunyai sekuriti makanan lebih berkemungkinan kekurangan vitamin D (AOR = 1.472, 95% CI = 0.953 - 2.273). Di samping itu, sebagai wanita, kemungkinan kekurangan vitamin D meningkat sebanyak dua kali ganda (AOR = 1.810; 95% CI = 1.181-2.772), manakala obesiti meningkatkan kemungkinan kekurangan vitamin D sebanyak lima kali ganda (AOR = 4.703; 95% CI = 2.312 - 9.566). Dalam fasa kedua kajian, suplementasi vitamin D3 selama dua bulan menambahbaikkan min FBS, TG, TC, LDL-C dan tekanan darah sistolik (p = 0.004, p = 0.001, p = 0.001, p = 0.003, p = 0.001 masing-masing), dan menghasilkan peningkatan yang signifikan bagi min kepekatan serum 25(OH) D dalam kumpulan intervensi berbanding kumpulan kawalan (p = 0.001). Tiada perbezaan yang signifikan didapati apabila status berat badan, WC, tekanan darah diastolik dan HDL-C dibandingkan di antara kumpulan intervensi dan kumpulan kawalan pada *baseline* dan selepas intervensi. Secara ringkasnya, kajian ini menunjukkan bahawa tahap ketidakjaminan makanan wujud secara signifikan di kalangan warta tua Iran, dan ianya berkait dengan faktor -faktor sosioekonomi dan susunan kediaman. Ini seterusnya mempengaruhi prevalens penyakit -penyakit kronik seperti kekurangan vitamin D dan penurunan kualiti hidup yang berkaitan kesihatan pada warga tua. Kekurangan vitamin D mempunyai kesan buruk terhadap kesihatan warga tua, sementara suplementasi vitamin D menambahbaikkan status vitamin D dan beberapa faktor-faktor risiko bagi

penyakit kardiovaskular. Oleh itu, penambahan semula tahap vitamin D di kalangan warga tua dapat mengurangkan morbiditi dan mortaliti pramatang pada warga tua yang mengalami ketidakjaminan makanan.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the Degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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ATP	Adult Treatment Panel
BMI	Body Mass Index
BP	Blood Pressure
CWHS	California Women's Health Survey
CM	Centimetre
CNPs	Child Nutrition Programs
CHD	Coronary Heart Disease
CVD	Cardiovascular Disease
DRI	Dietary Reference Intake
DBP	Vitamin D Binding Protein
EIA	Enzyme Immunoassay
FANTA	Food Nutrition Technical Assistance
FBS	Fasting Blood Sugar
FFQ	Food Frequency Questionnaire
FI	Food Insecurity
FIES	Food Insecurity Experience Scale
FM	Fat Mass
FS	Food Security
GI	Gastro Intestinal
HFIAS	Household Food Insecurity Access Scale
HDL-C	High Density Lipoprotein Cholesterol
HPLC	High Performance Liquid Chromatography
IU	International Unit
ICF	Informed Consent Form

IMOS	Iranian Multicentre Osteoporosis Study
IOM	Institute of Medicine
KG	Kilogram
LDL-C	Low Density Lipoprotein Cholesterol
LC-MS/MS	Liquid Chromatography-tandem Mass Spectrometry
MENA	Middle East and North Africa
MetS	Metabolic Syndrome
MOHME	Ministry of Health and Medical Education
NCEP	National Cholesterol Education Program
NIH	National Institutes of Health
NGO's	Non-Governmental Organisations
NSLP	National School Lunch Program
ODS	Office of Dietary Supplements
PHC	Primary Health Care
PIL	Patient Information Leaflet
PTH	Para Thyroid Hormone
RCT	Randomized Control Trial
RIA	Radioimmunoassay
ROS	Reactive Oxygen Specious
RRAS	Renin-Angiotensin Aldosterone System
SAT	Subcutaneous Adipose Tissue
SES	Socio Economic Status
SPF	Sun Protection Factor
SuRFNCD	Survey of Risk Factors for Non-communicable Diseases
T2DM	Type 2 Diabetes Mellitus

TC	Total Cholesterol
TG	Triglyceride
USDA	United States Department of Agriculture
VAT	Visceral Adipose Tissue
VDR	Vitamin D Receptor
VDSP	Vitamin D Standardization Program
WC	Waist Circumference
WIC	Women, Infants and Children
WHO	World Health Organization
25(OH)D	25-hydroxyvitamin D or calcidiol
1,25(OH)2D	1,25-dihydroxyvitamin D3 or calcitriol
7-DHC	7-dehydrocholesterol

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, Iran has witnessed a mixed economic growth transition and despite the global economic crises of 2008, Iran was listed within the developing and innovative countries in 2013 (World Bank, 2018). However, as a developing country, it shares the same concerns and challenges as any other developing country. Food insecurity, malnutrition and the overall poverty remains as one of the major concerns of the national government and the health organisations of the world wide. As a result, there has been a conscious decision globally to prioritise researches which focus on eliminating food insecurity and hunger worldwide [Food and Agriculture Organization (FAO), 2017].

There have been many attempts to define the concept of food security either as a research tool or a topic for policy development. Food insecurity could be defined as the social acceptance in low availability of safe and nutritionally adequate food as well as the low capacity of an acceptable food acquisition (FAO, 2017). In 2016, Food Insecurity Experience Scale (FIES) was proposed by FAO's as a new measurement of food insecurity. According to the FIES, food insecurity could be categorised as mild, moderate and severe. Mild food insecurity describes a situation on the margin between food secure and food insecure status. The experience of moderate food insecurity is characterised by an uncertainty and anxiety based on access to food with subsequent changes in the quality of the diet as the situation worsens. The change in diet quality may present itself as a less balanced, lacking essential vitamins and minerals as well as being a more monotonous diet (marginal-to-moderate food insecurity). With increasing severity of food insecurity, the quantity of food consumed decreases as portion sizes are often reduced or meals tend to be skipped (moderate-to-severe food insecurity). Severe food insecurity is defined by feeling hungry but not eating, or not eating for an entire day, often due to the lack of money or other resources (FAO, 2017). Based on the FIES definition, more than 689 million people in the world (approximately 9.3% of the world population) suffers from severe food insecurity (Smith et al., 2017). It is important to note that, food insecurity among economically constrained people does not necessarily mean they lack access to food; but people merely change their usual eating patterns to reduce overall daily intake due to the fear of running out of food (Bocquier et al., 2015).

In general, there is a relatively good understanding of food insecurity definition and measurement amongst healthcare providers (Gundersen & Ziliak, 2015). However, in many nations, there is a lack of understanding about the levels of food insecurity. For example, in Iran, there is little or no appreciation of the differences between mild, moderate and severe food insecurity amongst general population. Surprisingly, such inadequate understanding also exists amongst healthcare practitioners and policy

makers (Gholami et al., 2013). Food insecurity in older adults is a clinically relevant problem resulting in deleterious consequences on nutrition, physical and mental health and the quality of life (Bengle et al., 2010). The United States Department of Agriculture (USDA) reported that food insecurity among older adults in the US has risen from 16% to 18 % between 2005 and 2012, an alarming data from an economic superpower, suggesting that the challenges of food security affects not only low- and middle-income countries, but also effects the world most economically powerful country. Policy evaluations in the US has reported that food insecurity is a complex problem. It is a composite outcome of the individual or the families affected by an array of multiple and overlapping issues that includes affordable housing, social isolation, health problems, medical costs, and of course low pay packets (USDA, 2018). Furthermore, in older adults, food insecurity is significantly associated with a lack of social support and health problems which includes functional impairments (Janssen et al., 2001). In Iran, the prevalence of food insecurity among older females reported to be approximately 46% (Tavakoli & Dorosty-motlagh, 2016) a significantly higher proportion compared with that reported from the US. The higher food insecurity rate in Iran could reflect the overall economic status of the country and/or distribution of the wealth within the society, clearly underlining the challenges that the Iranian government and its health care providers face- food insecurity, malnutrition and the overall poverty. Interestingly, there are only a few published data available providing limited insights on the extent and severity of the food insecurity among the older adults in Iran, a growing population demographic. Thus, this study could provide a valuable information on the food insecurity in older adults and associated health related comorbidities.

Food insecurity has a strong association with socioeconomic status. Availability of food, stability of supply line over time and access to food production (Aquino et al., 2014) are the key determinants of the food security status. Food insecurity is often more prevalent among low income (economically poorer) households in both developing and the developed countries (FAO, 2017). Irrespective of an abundance of food and relative wealth, the issue of food insecurity is one experienced amongst high income countries. Whilst the existence of food insecurity in higher-income countries has been reported, there has been limited research examining the factors that contribute to food insecurity in these countries. Additional factors for higher income households include a fluctuating income, a sudden change in employment, a change in household composition, illness, disability, increased housing costs, and housing tenure (Olabiyi & McIntyre, 2014; Huang et al., 2010). The prevalence of food insecurity in the developed countries including was found to be 15% in New Zealand (Carter et al., 2010), 12.3% in Canada (Tarasuk et al., 2014), 13% in Australia (Russell et al., 2014), 8% in England, Wales, and Northern Ireland (U.K.) [Bates et al., 2017], and 14% in the United States (US) [USDA, 2014] living in a household with food insecurity.

In low-middle-income countries food insecurity affects low income families, especially the farmers and workers who are materially and financially unable to use the facilities provided by the national economic growth (McGuire, 2015). Food insecurity is strongly associated with economic disadvantages especially among those

with lower educational background, having difficulty to save money, native households and families with more children (Hamad, 2016). Low socioeconomic background exacerbates food insecurity due to increasing food cost which in turn dictates people's food choice, frequently limiting spending on food to make room for other necessities such as utilities and housekeeping expenses (Bocquier et al., 2015). Food security indicates 'accessibility to sufficient food for all people at all times for a healthy and active life" (Campbell, 1991). Food security and a good access to healthy food are important determinants of basic human health. Studies have shown that food insecurity were significantly associated with obesity, type 2 diabetes mellitus (T2DM) [Mahmoodi et al., 2017; Heerman et al., 2016; Bhargava & Lee 2016; Seligman et al., 2009], and diseases often linked with overeating which suggests a paradoxical outcome of food insecurity and obesity. Interestingly, in low and middle income countries, obesity is primarily linked with higher income level- affluent families tend to have higher rate of obesity and T2DM, a consequence of obesity status (Ziraba et al., 2009). Thus, it is vital to note that there are common diseases (obesity, hypertension, diabetes) which are linked to food insecurity in certain societies (Campbell, 1991) and food security in another society.

People with food insecurity were more likely to have hypertension, coronary heart disease and congestive heart failure (Gregory & Coleman-jensen, 2017). Food insecurity has been reported to be significantly associated with increased concentration of low-density lipoprotein cholesterol (LDL-C) and poor glycaemic control, especially among diabetic patients (Bawadi et al., 2012; Seligman et al., 2012), suggesting that food insecurity is not merely physical absence of available food but rather the quality of the available food also contributes significantly to food insecurity status. People with cardiometabolic disease were more susceptible to food insecurity compared to those without the disease (13.0% vs. 5.8%) [Berkowitz et al., 2017]. Moreover, food insecurity is significantly associated with being underweight, highlighting how malnutrition or poor diet quality plays an important role in the association between food insecurity and nutritional status (Walrod et al., 2018; Mirshekar et al., 2017; Rivera-Márquez, 2005), probably contributed by the lack of the physical availability of food component of the food insecurity. Furthermore, food insecurity may interfere with the adherence to specific dietary recommendations thus having a significant negative association with cardiometabolic disease prevention and treatment. Therefore, it is plausible to consider that clinical management of food insecurity by nutrition consultants could provide important positive implications on the health status of those affected with food insecurity (Berkowitz et al., 2017).

Food insecurity is proposed as a core variable for understanding the nutritional status of a person especially in a low income population (Darmon & Drewnowski, 2015). Food insecurity may be experienced at the household and at individual levels usually contributing to a poor health, nutrition and functional outcomes among children, women and older adults (Pfeiffer et al., 2015; Campbell, 1991). Diets of food insecure people are habitually poor in quality and have lower levels of micronutrients. Food insecurity, reduced diet quality and nutrient intakes (Champagne et al., 2007; Dixon et al., 2001) have been linked to a compromised health status and diet-related chronic diseases (Holben & Pheley, 2006). Studies have reported a significant association

between food insecurity and poor-quality diet consumption (Davison et al., 2017; Do Nascimento Jacinto de Souza & Marín-León, 2013). People with food insecurity have systematically lower nutrient intakes and lower consumption of dairy products, fruits and vegetables, and in some cases, meat, and meat alternatives (Bhargava & Lee, 2016). Higher carbohydrate intake, oils (fat) and less fibre intake were significantly associated with food insecurity in adults. What is important to note is the significant direct relationship between food insecurity and dietary micronutrient deficiencies including calcium, zinc, iron, thiamine, riboflavin, niacin, folic acid, folate, vitamin D, C, A, E and magnesium (Bolland et al., 2014; Bandayrel et al. 2011; Bartali et al., 2006; Dixon et al., 2001). Therefore, it would be a valuable effort to replenish vitamin and essential mineral deficiencies in food insecure population to prevent or at least to reduce negative impact on health and well-being of those affected. One of the micronutrient that requires further attention among food insecure older adults is vitamin D (Egeland et al., 2011; Ziliak & Gundersen, 2011). Vitamin D is naturally produced when exposed directly to sunlight; sunlight exposure may be comparable with the measures of food insecurity (Otero et al., 2015). In a study by Cashman et al (2016), 40% of older adults (> 50 years old) from 14 European countries, have serum 25(OH)D concentrations less than 30 nmol/L. A recent meta-analysis reported a remarkably higher (62%) rate of vitamin D deficiency in Iranian women (Tabrizi, Moosazadeh, et al., 2018). Low dietary intake, insufficient exposure to sunlight, reduced skin thickness, reduced intestinal absorption, damaged hydroxylation in the liver and kidneys, and decreased outdoors activity leads to increased risk of developing vitamin D deficiency in older adults (Muscogiuri et al., 2017; Lee et al., 2008), thus low plasma levels of vitamin D may have a direct association with food insecurity (Tse et al., 2016). Vitamin D plays an important role in fighting diseases, reducing depression and boosting excess weight loss, therefore vitamin D deficiency may indirectly worsen the outcome of food insecurity (Bartali et al., 2006). Amongst many physiological roles, vitamin D affects bone, teeth and muscle structure and functions. Vitamin D deficiency could lead to osteomalacia-induced pain in adults- a debilitating condition (Schwalfenberg & Genuis, 2015). Thus, in food insecure population, adequate levels of vitamin D may in turn compensate, at least to some extent, the negative effects of food insecurity on bone and muscle structure and functions (Muscogiuri et al., 2017; Zhang et al., 2019). Research in developing countries has established that dietary supplementation improves vitamin D status leading to enhanced calcium and phosphorus absorption resulting in an improved overall bone and teeth health and enhanced immune system function improving natural resistance against various diseases (Bolland et al., 2014) further highlighting the importance of vitamin D in human health and disease.

Latitudes from 12° N to 48° N in different countries of the Middle East such as Iran, Kuwait, Saudi Arabia, Lebanon, Turkey, Jordan and United Arab Emirates is an optimal environment for natural vitamin D synthesis. Despite that, the Middle Eastern countries have one of the highest prevalence of risk factors and health consequences of vitamin D deficiency and insufficiency (Mithal et al., 2009; El-Hajj Fuleihan, 2009; Heshmat et al., 2008). Even with abundant sunshine, several studies show that the prevalence of vitamin D deficiency has increased in the Middle Eastern population in most ages (reduction from about 25 nmol/L to 10 nmol/L) [Van Schoor & Lips, 2011; Mithal et al., 2009], which clearly outlines a disconnection between availability of

optimal environment for vitamin D production and the actual concentration of vitamin D in those population. Similarly, a meta-analysis of 48 studies from Iran consisting of 18531 individuals with vitamin D deficiency reported a remarkably high levels of vitamin D deficiencies in Iranian adult population (male, female, and pregnant women as 45.64%, 61.90% and 60.45%, respectively) [Tabrizi et al., 2018]. The causes of vitamin D deficiency as well as the factors that may increase their risk for low vitamin D in the Middle East countries remains to be fully elucidated. However, cultural practices including bespoke clothing and veils of Muslim women as well as their lifestyle of staying indoors may contribute to vitamin D deficiencies seen in those societies (Kelishadi et al., 2016; Wacker & Holick, 2013; Van Schoor & Lips, 2011). Nonetheless, there is no clear understanding of vitamin D deficiency pattern and its contribution to food security in Iran which merits further investigation.

Vitamin D deficiency and insufficiency has become a global pandemic problem affecting more than one billion children and adults worldwide (Holick, 2017). A number of studies have reported an association of vitamin D deficiency with several acute and chronic illnesses such as musculoskeletal disease (Jones & Hansen, 2009; Huotari & Herzig, 2008), cardiovascular diseases (Kheiri et al., 2018; Gallagher et al., 2013; Scragg, Camargo, & Simpson, 2010), metabolic Syndrome (MetS) (Raj et al., 2005; Ford et al., 2005; Mosekilde, 2005) and its risk factors such as high blood pressure, high blood sugar, obesity and dyslipidaemia (Alaklabi & Alsharairi, 2018; Awad, Alappat, & Valerio, 2012; Baz-Hecht & Goldfine, 2010; Maddaloni et al., 2018). Ageing related reduced cutaneous synthesis is one of the main contributing factors to vitamin D deficiency in older adults (MacLaughlin & Holick, 1985).

Metabolic syndrome (MetS) is a disorder characterised by a cluster of inter-related metabolic disturbances (Gardner-Sood et al., 2015; Eckel et al., 2005). MetS is defined by a myriad of increased fasting plasma glucose (FPG), abdominal obesity, high triglyceride (TG) levels, reduced high-density lipoprotein cholesterol (HDL-C), and high blood pressure (BP) [Eckel et al., 2005]. Aging population, profound change in lifestyle leading to obesity has resulted in increased MetS prevalence which is estimated to be approximately 25% of all adults worldwide (Saklayen, 2018)(Nolan, Carrick-Ranson, Stinear, Reading, & Dalleck, 2017). The prevalence of MetS is increasing worldwide. The age-adjusted prevalence of MetS increased from 29.2% to 34.2% in the US according to data from the National Health and Nutrition Examination Survey (NHANES) III and NHANES 1999 - 2006 (Mozumdar & Ligouri, 2011). This increasing trend has also been observed in countries like Korea and Iran and presents a major challenge for public health professionals in becoming a social and economic problem in the near future (Sarrafzadegan et al., 2012; Kim et al., 2008).

The prevalence of MetS is growing globally. It has been shown in all adult demography. In 2012, the prevalence of MetS among Iranian older adults was 29% (Sarrafzadegan et al., 2012), indicating 1 in every 3 older adults is at high risk of MetS related premature morbidity and mortality. Several epidemiological studies have suggested that lower 25(OH)D concentrations may contribute towards a higher

prevalence of MetS (Vitezova et al., 2015; Bea et al., 2015; Mutt et al., 2019). Moreover, vitamin D supplementation had a beneficial effect on the components of MetS (Mutt et al., 2019; Farag et al., 2018). The exact mechanism(s) of vitamin D deficiency-induced metabolic syndrome is not fully elucidated yet. However, studies suggest that vitamin D deficiency triggers renin-angiotensin-aldosterone system (RAAS), leading to hypertension and if untreated to left ventricular hypertrophy over time. In addition, lack of vitamin D can lead to an increase in parathyroid hormone (PTH), which heightens insulin resistance and influences the onset of T2DM, hypertension, inflammation, and increased cardiovascular disease (CVD) risk (Elamin et al., 2011). Considering these data, it is plausible to consider that supplementation of vitamin D in Iranian food insecure, vitamin D deficient older adults could improve markers of metabolic syndrome. MetS *per se* a major risk factor for cardiac death (Sung et al., 2015; Tenenbaum & Fisman, 2011) with elevated blood pressure, impaired fasting glucose, and low high- density lipoprotein (HDL-C) component being major contributor to risk of sudden cardiac death (Hess et al., 2017). Therefore, this aims to elucidate if vitamin D supplementation would improve MetS, reducing the risk of cardiovascular disease and premature mortality. Hence, in second section of this study, the effects of vitamin D supplementation on MetS markers in food insecure, vitamin D deficient older adults will be assessed.

In summary, convincing data indicates that lack of access to food, having low household income, food insecurity and decreased nutrient intake leads to a variety of health problems. Micronutrient deficiency due to continuous food insecurity can lead to premature morbidity and mortality in the older adult population. A cross-sectional study has reported an association between high energy dietary pattern and low consumption of essential nutrients with MetS (Mirmiran et al., 2014), suggesting that poor diet plays an important role in pathophysiology of MetS. Similarly, limited availability of nutritious food such as whole bran grain, fruits, vegetables and the greater intake of fatty food in adults has been associated with food insecurity (Morales & Berkowitz, 2016).

1.2 Problem Statement

Globally, there is a trend in increased life expectancy over the past three decades resulting in a marked increase in the proportion of adults over 60 years (ONU, 2015). In 2015, Iran's Centre for Statistics (ICS) revealed that 8% of the total population (6,200,000 people) were aged over 60 years and this rate is expected to increase up to 26% by 2050 (United Nation, 2015). The anticipated growth in the number of the older adult population would bring a greater demand on the public health service such as medical care and social amenities. Older adults, in particular those from a low socioeconomic status, often face lifelong challenges which may include unexpected injuries, disability, leading to potential chronic diseases with significantly reduced quality of life, ultimately posing a profound negative impact on long-term medical and social health care cost (Prince et al., 2015).

Increased premature morbidity presents a real barrier for food accessibility and availability among older adults. For example, physical limitations stemming from chronic musculoskeletal, CVD or respiratory disease will undoubtedly limit affected persons' ability for food shopping and/or preparing adequate meals (Ishikawa et al., 2016), indirectly influencing the food security status. Thus, it is reasonable to consider that severe food insecurity among older adult population is not solely due to limited financial resources whilst accessibility could also be an important risk factor in food insecurity (Yadegari et al., 2017; Coles et al., 2016).

Despite emerging evidence reporting that low income, limited mobility and poor health among older adults are more likely to put them at a greater risk for various problems including food insecurity (Russell et al., 2014), poverty is considered as the primary factor limiting household resources (Bickel et al., 2000). Poverty is represented by unemployment, under-employment, low household income and high social dependence, factors which are more prevalent among older adults (Jacques et al., 2018). However, the direct influence of low income with food insecurity is yet to be studied in older adult population. Therefore, identifying the risk factors of food insecurity among older adult will provide better insight to overcome food insecurity. A study in the US has reported that food insecurity is negatively associated with income, education, home ownership, and age whilst unemployment, disability, and a state's tax burden are positively contributing towards food insecurity (Leitz, 2018). Furthermore, ethnicity, citizenship and participation in nutrition assistance programme influencing food security status. All the above factors will also influence the extent of food insecurity in Iran. Iran is a country with significant variations in the level of education, employment, home ownership, income and the dietary habits, all of which could affect food security status.

A number of studies have identified correlations between sociodemographic characteristics with household food insecurity (Ghattas et al., 2015; Hakim et al., 2010). However, the impact of food insecurity on nutrients intake among older adults is not well understood yet. Among adults, poor or limited food choice would lead to suboptimal nutrient intakes, which could be considered as an indicator of food insecurity (Davison et al., 2017). Lower energy and nutrient intakes including vitamin D are highly associated with food insecurity in both adults and children (Kirkpatrick et al., 2015; Mark et al., 2012). Furthermore, low level vitamin D in younger adults (>18 years old) appears to be the outcome of food insecurity (Egeland et al., 2011), suggesting that food insecurity phenomenon could affect all walks of the society as well as the degree of nutritional intake. Yet, there is no information on the association between food insecurity and vitamin D status among older adults above 60 years in Iran. This study will examine extent of vitamin D deficiency in food insecure older adults. Due to cultural dress code constraints on female population, the extend of vitamin D deficiency may vary between males and females (Tabrizi et al., 2018). This difference is anticipated to be more pronounced in older adults, thus having a greater negative impact on their health leading to an increase in premature morbidity and mortality. Similarly, older male population dwelling alone may have potentially limited capability/capacity to prepare optimal nutritional food may profoundly contribute to food insecurity (Gholami et al., 2013). Moreover, it is plausible to

hypothesis that the physiological differences between male and female (eg: menopause, post-menopausal increased risk of CVD disease) would also influence the outcome of food insecurity (WHO, 2015). Therefore, this study is set out to evaluate the influence of gender on food insecurity as well as its impact on plasma levels of vitamin D in older Iranian adults.

Numerous studies in the developed countries in North America and the Europe, have reported an association between food insecurity and decreased dietary intake in adults (Cashman et al., 2016; Egeland et al., 2011; Ziliak & Gundersen, 2011; Lee et al., 2008), but there are no reports of studies outlining the link between food insecurity and decreased dietary intake in older adults. Moreover, findings from studies in Western countries may not be applicable to developing countries such as Iran, due to profound differences in the diets and lifestyles in Middle Eastern countries (Hwalla et al., 2017). Thus, it is important to design a dedicated study to increase our understanding of the degree of food insecurity in older Iranian adults and its influence on nutritional values such as plasma vitamin D levels.

Several epidemiological studies have reported an association between low vitamin D status and the development of MetS (Ford et al., 2005; Liu et al. 2005). For example, a few observational studies have reported associations between low concentrations of circulating serum 25(OH)D level and increased risk of a number of important debilitating medical conditions, including osteoporosis, diabetes, and cardiovascular diseases (CVD) [Song et al., 2013; Robinson-Cohen et al., 2013]. The use of vitamin D supplementation in adults to prevent osteoporosis is well accepted with a recommended daily dose of 800 IU (IOM, 2010). Similarly, a number of studies have reported positive impact of vitamin D supplementation on MetS (Salekzamani et al., 2016; Witham et al., 2013). The exact biological mechanism on the role of vitamin D in the development of risk factors of MetS is not fully elucidated but vitamin D supplementation has been considered as an effective tool in alleviating deleterious effects of vitamin D deficiency in general population (Kim, 2015; Bea et al., 2015; Al-Daghri et al., 2014). Nonetheless, there is little or no information on the effectiveness of exogeneous vitamin D supplementation in food insecure older adults. Hence, this study aims to explore the hypothesis that vitamin D supplementation in food insecure older adults would counteract plasma vitamin D deficiency and alleviate MetS risk factors, ultimately improving general health of the older adults.

1.3 Justification

There is an inverse correlation between vitamin D status and food insecurity. The greater level of food insecurity leads to greater level of vitamin D deficiency (Mark et al., 2012; Egeland et al., 2011). The results of previous studies revealed that significant deficiencies of vital nutrients intake including vitamin D were present among food insecure individuals. This appears to be more pronounced amongst vulnerable section of the society including the older adults. There are significant challenges for some older adult (> 60 years old) to have optimal plasma vitamin D levels and often remain in a chronic state of vitamin D deficiency. Low dietary intake,

insufficient exposure to sunlight, reduced skin thickness, weak intestinal absorption, damaged hydroxylation in the liver and kidneys, and decreased outdoors activity (Muscogiuri et al., 2017; Lee et al., 2008) all of which contributes to chronic vitamin D deficiency.

According to the 2nd National Integrated Micronutrient Survey (NIMS; 2012-2013) vitamin D deficiency is highly prevalent in Iran affecting more than 80% of Iranians in all age groups (UNICEF, 2014). For older adults to attain a serum 25(OH)D level of 75 nmol/l (30 ng/ml) the dose of vitamin D supplementation should be between 20 to 25 µg/day (800 to 1000 IU/day). Exogenous intakes may have to be increased to as much as 50 µg (2000 IU) daily for older adults suffering from osteoporosis with limited sunlight exposure (e.g. housebound or institutionalised) or having gastroenterological problems such as malabsorption (Holick et al., 2011). Therefore, it is plausible to consider that exogenous vitamin D supplementation in older adults could play a vital role in preventing untoward effects of chronic vitamin D deficiency. To the best of our knowledge this is the first study in Iran focusing on both observational and interventional approaches on vitamin D status, food insecurity, and MetS. The outcome of this study could provide new evidence on the extent and the impact of food insecurity and its detrimental influence on vitamin D status. In addition, this study aimed to investigate the effect of vitamin D supplementation among one of the most vulnerable section of the society, food insecure and vitamin D deficient older adults on MetS parameters. The reason for focusing on MetS stems from the fact that metabolic syndrome has shown to be a major risk factor of cardiovascular disease (Hess et al., 2017; Sung et al., 2015; Tenenbaum & Fisman, 2011). Cardiovascular disease is a major cause of premature morbidity and mortality in Iran (Sadeghi et al., 2017). The finding from this study could provide an extensive wealth of insight into our current perception of food security in the older adult and improve our understanding of how to identify strategies to prevent CVD.

The determination of food insecurity and vitamin D status among older adults is an important first step for future programs of nutritional research aimed to reducing the incidence of vitamin D deficiency and its consequences including MetS parameters in this vulnerable population. There are numerous observational studies indicating a direct association between MetS risk factors and low serum 25(OH)D concentrations in observational studies as will be discussed in (Table 2.2). However, reports from clinical trials have been proven to be inconsistent (Table 2.2) probably due to difference in population cohorts, sample size and background comorbidities- all merit further investigation. Therefore, there seems to be an unmet need to ascertain the true impact of vitamin D on MetS especially amongst food insecure older adults. Thus, upon understanding the association between food insecurity and vitamin D status, this study could improve our approach to vitamin D supplementation policy to reduce parameters contributing to MetS in older adult population. Indeed, national programmes of vitamin D supplementation (fortification of milk in Finland since 2003) have reported reduction in MetS (Mutt et al., 2019). Moreover, the finding from this study could be utilised to assist the health care professionals and the Iranian Ministry of Health in developing dietary recommendations based on the status of food insecurity and suboptimal or inadequate nutritional intake amongst most vulnerable

groups of the society including development of an appropriate guidelines and policy outlines for vitamin D supplementation in older age adult populations.

1.4 Research of study

1.4.1 Research questions of Phase one

1. What is the prevalence of food insecurity among older adults in Iran's Karaj city?
2. What is the prevalence of the vitamin D deficiency among older adults in Iran's Karaj city?
3. What is the characteristics in terms of :
   a. socioeconomic
   b. medical history (history of diabetes, dyslipidaemia, hypertension, medication, history of vitamin D supplementation and history of any diseases)
   c. blood pressure
   d. sunlight exposure level
   e. anthropometric measurements [weight, height, body mass index (BMI) and waist circumference (WC)]
   f. dietary intake (energy, macronutrients and micronutrients) among older adults in Iran's Karaj City?
4. Are there any association between a) socioeconomic characteristics, b) medical history and c) food security status among older adults?
5. Is there any difference between f) anthropometric measurements, g) dietary intake, i) blood pressure and d) vitamin D status according to food security status after adjusting for covariates among older adults?
6. Are there any association between a) socioeconomic characteristics, b) medical history, e) sunlight exposure and d) vitamin D status among older adults?
7. Is there any difference between f) anthropometric measurements and g) dietary intake i) blood pressure according to vitamin D status after adjusting for covariates among older adults?

1.4.2 Research questions of Phase two

i. Is there any significant difference in baseline sociodemographic characteristics between intervention and control groups?
ii. Is there any significant difference between and within intervention and control groups after 2 months of vitamin D supplementation in terms of?
   - serum 25(OH)D concentration,
   - MetS parameters [body mass index (BMI), waist circumference (WC), blood pressure (BP), total cholesterol (TC), triglyceride (TG), low-density lipoprotein (LDL-C), high-density lipoprotein (HDL-C) and fasting blood sugar (FBS)],
   - dietary intake (energy, macro and micro nutrients)

1.5 Objectives of the study

This study consists of two phases (phase one and phase two) with predefined objectives for each phase as outlined below.

1.5.1 General objective of Phase one

To determine the prevalence and factors associated with food insecurity and vitamin D deficiency among older adults in Karaj city, Alborz province, Iran.

1.5.1.1 Specific objectives of Phase one

1. To determine the:
    a. socioeconomic characteristics
    b. medical history
    c. blood pressure
    d. food security status
    e. vitamin D status
    f. sunlight exposure level
    g. anthropometric measurements (weight, height, BMI and WC)
    h. dietary intake (energy, macronutrients and micronutrients) among older adults in Iran's Karaj City.
2. To assess associations between socioeconomic characteristics, medical history and food security status among older adults.
3. To evaluate differences between anthropometric measurements, blood pressure, dietary intake and vitamin D status according to food security status after adjusting for covariate factors among older adults.
4. To assess associations between socioeconomic characteristics, medical history and sunlight exposure according to vitamin D status among older adults.
5. To evaluate differences between anthropometric measurements, dietary intake and blood pressure according to vitamin D status after adjusting for covariate factors among older adults.

1.5.2 General objective of Phase two

To assess the effect of vitamin D supplementation on MetS parameters (BMI, WC, BP, TC, TG, LDL-C, HDL-C, FBS) as well as 25(OH)D concentration among food insecure and vitamin D deficient older adults in Karaj city, Alborz province, Iran.

1.5.2.1 Specific objectives of Phase two

i. To compare baseline sociodemographic characteristics between intervention and control groups.
ii. To analysis significant difference between and within intervention and control groups after 2 months of vitamin D supplementation in terms of:
   - serum 25(OH)D concentration,
   - MetS parameters (BMI, WC, BP, TC, TG, LDL-C, HDL-C, FBS) and
   - dietary intake (energy, macro and micro nutrients)

1.6 Null hypothesis of the study

1.6.1 Null hypothesis Phase one

1. There is no significant difference among older adults in terms of:
   a. socioeconomic characteristics
   b. medical history
   c. blood pressure
   d. food security status
   e. vitamin D status
   f. sunlight exposure
   g. anthropometric measurements (weight, height, BMI and WC)
   i. dietary intake (energy, macronutrients and micronutrients) among older adults Iran's Karaj City.
2. There is no significant association between socioeconomic characteristics, medical history and food security status among older adults.
3. There is no significant difference between anthropometric measurements, dietary intake, blood pressure and vitamin D status according to food security status after adjusting for covariate factors among older adults.
4. There is no significant association between socioeconomic characteristics, medical history and sunlight exposure according to vitamin D status among older adults.
5. There is no significant difference between anthropometric measurements, dietary intake and blood pressure according to vitamin D status after adjusting for covariate factors among older adults.

1.6.2 Null hypothesis Phase two

i. There is no significant difference in baseline sociodemographic characteristics between intervention and control groups.
ii. There is no significant difference between and within intervention and control groups after 2 months of vitamin D supplementation in terms of:
   - serum 25(OH)D concentration,
   - MetS parameters (BMI, WC, BP, TC, TG, LDL-C, HDL-C, FBS) and
   - dietary intake (energy, macro and micro nutrients)

1.7 Conceptual framework of research study

The conceptual framework of the research study is shown in Figure 1.1. It shows the relationship between household food insecurity and vitamin D status, potential risk factors, nutritional and health outcomes. The research framework includes the potential risk factors of household food insecurity and vitamin D status including; socioeconomic characteristics [gender, age, educational level, occupation, living situation, ethnicity, household monthly income, financial support, supplementary food support, ownership of the home they in, monetary savings, living space and basic living facilities and estimation of the money spent monthly (T) on main needs] and medical history (history of diabetes, dyslipidaemia, hypertension, medication, history of vitamin D supplementation and history of other co-morbidities).

An element of food insecurity is access to adequate nutritionally valuable food that is directly linked to the individuals' own health. This is more pronounced if individuals live on their own with little or no additional care support. Lacking optimal health could ultimately mean losing the ability/capability to work, venture out to purchase the right food or even enjoy fresh air and sunshine. Although exposure to the sunlight is a major factor affecting total serum vitamin D levels, food insecurity may also result in a decreased essential nutrient intake (Bolland et al., 2014; Bandayrel et al., 2011) which could indirectly contribute to vitamin D deficiency thus providing evidence of an association between vitamin D deficiency and food insecurity (Kirkpatrick et al., 2015; Hanson & Connor, 2014). Therefore, it is plausible to assume that there is a profound linkage between the food insecurity and vitamin D status. On the other hand, food insecurity and vitamin D status can also affect the overall nutritional status of the older adults. Numerous studies have identified food insecurity and vitamin D deficiency as potential risk factors for several chronic diseases among males and females. Interestingly, the opposite also seems to be true. Studies have reported that development of chronic disease may deteriorate the condition of food insecurity and vitamin D deficiency (Mohajeri et al., 2017; Gundersen & Ziliak, 2015). It can have profound negative impacts on anthropometric measurements (weight, height and BMI and WC) and the total dietary intake (total energy, macro- and micronutrients levels). Interestingly, low household income related to poor dietary intake as well as obesity, diabetes, hypertension as the outcome of food insecurity could also play a vital role in nutrient deficiency such as vitamin D deficiency which could in turn lead to increased parameters of MetS as will discussed in Table 2.1 (Krassilnikova et al., 2014). MetS in turn could also influence vitamin D deficiency and contribute to food insecurity (access to adequate nutritionally valuable food) thus indicating a complex picture between chronic diseases, food insecurity and vitamin D deficiency in older adults. Nutritional supplementation has been linked to enhanced health status and prevention of diet-related chronic diseases (Zemel, 2013; Holben & Pheley, 2006). Vitamin D dietary supplementation improves serum 25(OH)D levels leading to improved gut absorption of calcium and phosphorus for better bone and teeth health and enhanced immune system function (Bolland et al., 2014), body weight control (Asemi et al., 2015) and MetS (Chung-Min et al., 2018). The research framework was based on (Campbell, 1991) conceptual framework. In summary, low household income appears to be a significant risk factor for food insecurity, resulting in MetS parameters.

Therefore, vitamin D supplementation in older adults could be beneficial in the management of MetS parameters.

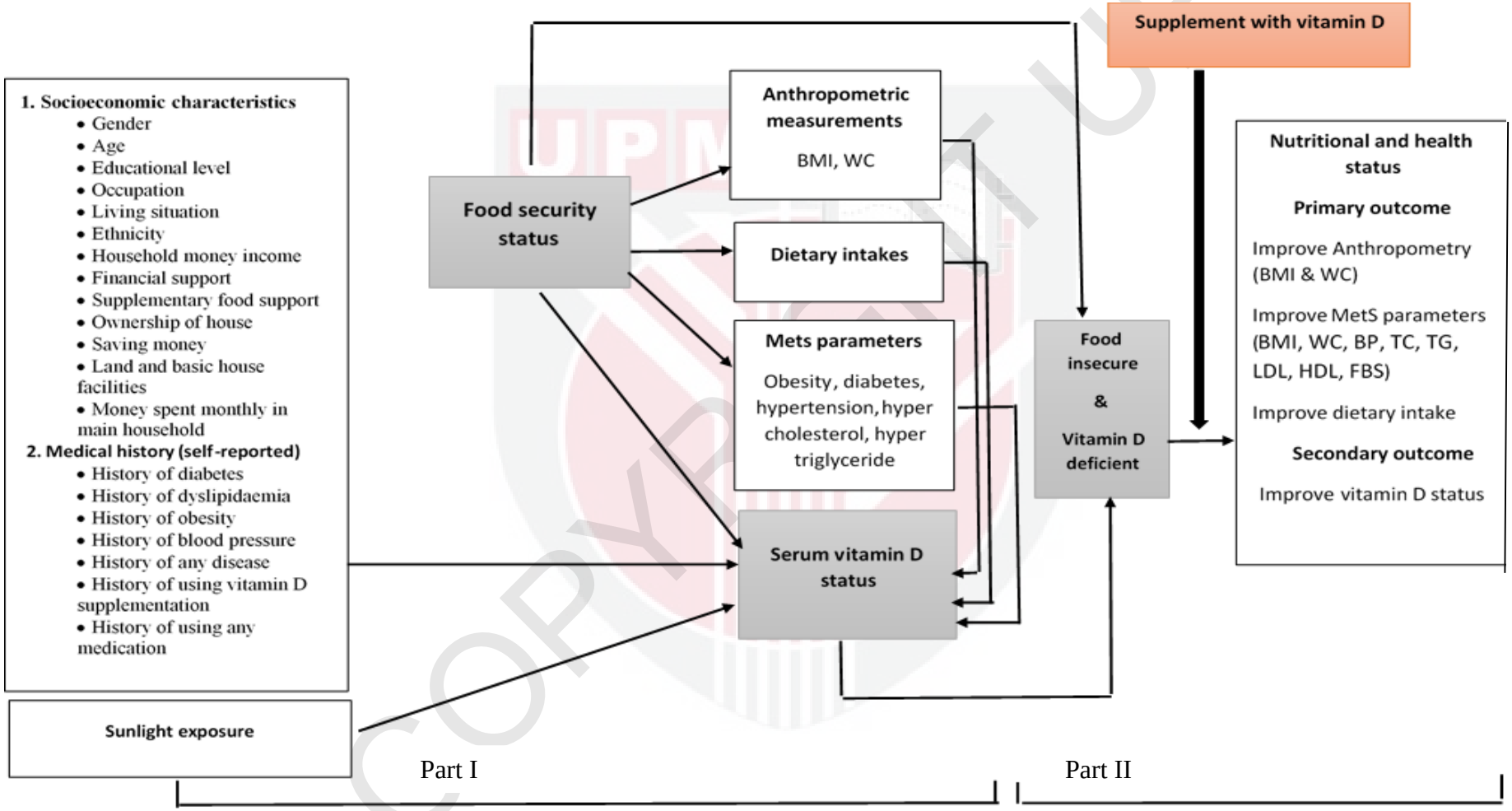

Figure 1.1 : Conceptual framework of research study

1.8 Definition of terms

1.8.1 Food insecurity

The USDA defines food insecurity as “the state of being without reliable access to a sufficient quantity of affordable, nutritious food”(USDA, 2014). There are four key terms in that definition: access, sufficient quantity, affordable and nutritious.

1.8.2 Older adult

Old age comprises "the later part of life; the period of life after youth and middle age, usually with reference to deterioration". The United Nations has defined 60+ years to be denoted as old age and this is the first international definition of old age (World Population Aging, 2015). The UN agreed cut off is 60+ years to refer to the older or elderly persons. Within the elderly population, further classification like oldest old (normally those 80+) and centenarian (100+) and even super-centenarian (110+) are also made). One study distinguishes the young old (60 to 69), the middle old (70 to 79), and the very old (80+) [Forman et al., 1992].

1.8.3 Vitamin D Deficiency

Vitamin D deficiency has been defined and recently recommended by the Endocrinology & Metabolism Research Centre Iran (EMRC) as a serum 25(OH)D level of less than 20 ng/ml or ≤ 50 nmol/L *(*Endocrinology & Metabolism Research Centre of Iran, 2013; Holick et al. 2011).

Serum vitamin D levels were classified according to Endocrinology & Metabolism Research Centre of Iran

1) < 20 ng/mL or ≤ 50 nmol/L = vitamin D deficiency
2) 20 - 30 ng/mL or 50-75 nmol/L = insufficient amount of vitamin D
3) 30 - 100 ng/mL or 75-200 nmol/L = sufficient amount of vitamin D

1.8.4 Metabolic syndrome (MetS)

According to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) [Luk et al., 2008] and National Heart, Lung and Blood Institute (NIH), definition of MetS is present if three or more of the following five criteria are met:

WC > 90 cm (35 inch) in Iranian men and women, BP > 130/85 mmHg, TG > 1.7 mmol/L (>150 mg/dL), HDL < 1.04 mmol/L (< 40 mg/dl) in men; HDL <1.3 mmol/L (< 50 mg/dl) in women and FBS > 5.6 mmol/L (>100 mg/dl).

1.8.5 Waist circumference (WC)

WHO has defined cut-points for abdominal obesity around one or both of these measurements, with same cut-points for men and women > 90 cm (Esteghamati et al. 2008; WHO 2008).

1.8.6 Body mass index (BMI)

BMI is measured as weight in kilograms divided by the square of height in metres. Obesity is BMI > 30 kg/m^2 (WHO, 2000).

1.8.7 Blood pressure (BP)

The measurement is done on the right upper arm in a sitting position and after taking a rest for a few minutes. The grade one hypertension is BP > 130/85 mmHg (Muntner et al., 2018; WHO/ISH, 1999).

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LIST OF PUBLICATIONS

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