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Comparison of Micronutrient Intakes from Food with Dietary Reference Values in a Lebanese Adult Sample

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ABSTRACT

Background: Micronutrients which include vitamins and minerals are present in small quantities in food and are essential in a healthy diet for disease prevention and well-being. They enable the body to produce enzymes, hormones and other substances and provide a range of critical biological functions.

Objective: The objective of this study was to quantify and compare the dietary intakes of 19 micronutrients to recommended micronutrient intakes, in order to identify inadequate/ excess micronutrient intakes among a sample of Lebanese adults.

Subjects and methods: Dietary Intakes of individuals from different areas in Lebanon were assessed using the US National Institute of Health (NIH) diet history questionnaire, in a cross-sectional nutrition survey conducted between 2009 and 2011 on a convenience sample of 657 (259 males and 398 females) Lebanese adults aged 19-70 years. Mean/ median dietary intakes were calculated and then compared with the estimated average requirements (EARs)/ for some micronutrients and adequate intakes (AIs) for others, along with the tolerable upper level intakes (ULs) of the studied micronutrients to identify inadequate/ excess intakes, respectively.

Results: In both genders and all age groups, mean intakes of vitamin D were significantly lower than the EAR, and mean calcium intakes were also lower than the EAR among females in the late adult age group. Mean potassium intakes among both genders and almost all age groups were higher than the AI. Furthermore mean intakes of magnesium and sodium were significantly higher than the EAR and AI, respectively, and also higher than the UL among all age groups of both genders.

Conclusion: Certain vitamins and minerals with potentially significant health implications are under-recognized. These findings may provide a foundation for developing public health policy and regulatory decisions relating to fortification of essential foods with vitamins and minerals of concern and supplementation of individuals at risk of developing deficiencies or with deficiencies to ensure adequate consumption of micronutrients. Awareness campaigns should also be designed and implemented to increase awareness related to dietary sources of micronutrients and the potentially serious health implications associated with their deficiencies. Further research should be employed on different groups such as children, pregnant women and the elderly.

Keywords: Micronutrients intake, vitamins, minerals, Lebanese adults

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LIST OF ABBREVIATIONS

AI Adequate Intake

DRI Dietary Reference Intake

EAR Estimated Average Requirement

FFQ Food Frequency Questionnaire

IOM Institute of Medicine

IU International Units

LRNI Lower Reference Nutrient Intake

NIH National Institute of Health

RDA Recommended Dietary Allowance

UL Tolerable Upper Intake Level

INTRODUCTION

Micronutrients which include vitamins and minerals are present in small quantities in food and are essential in a healthy diet for disease prevention and well-being. They enable the body to produce enzymes, hormones and other substances and provide a range of critical biological functions including skeletal development, growth, development of the brain and the nervous system, immune function and eye function (Investing in the future, 2009; Shenkin, 2006). Most vitamins cannot be synthesized by the human body and must be ingested in the diet in small quantities to facilitate normal metabolism. Minerals are found in varied foods and have different functions in the body such as building blood and strong bones, transmitting nerve impulses and maintaining a normal heart beat. Interest in the amounts of micronutrients ingested has increased especially that inadequate micronutrient intake contributes to the global burden of disease (Ezzati *et al.*, 2002). Micronutrients are needed in minute amounts where the dietary requirement of a micronutrient is defined as an intake level which meets specific standards for adequacy. The Institute of Medicine has set recommended nutrient reference values known as Dietary Reference Intakes (DRIs) based on age, gender and life stage (IOM 2003).

Around the world, at least 2 billion people live with vitamin and mineral deficiencies (Micronutrient Initiative, 2009). Certain deficiencies particularly those of vitamin A, iodine, iron, zinc and folate are very critical in global public health terms; their lack signifies a major risk to the health of populations. Deficiencies or excesses of certain micronutrients lead to serious complications and diseases (Micronutrient Initiative, 2009).

LITERATURE REVIEW

Micronutrient intake in Western countries

Many developed and developing countries around the world appear to have shortages and excesses of several micronutrients. The usual nutrient intakes of 16 micronutrients by schoolchildren (9-13 year old), adults (40-60 year old) and post-menopausal women (50–75 year old) in Greece were collected in a cross sectional study. The prevalence rates of inadequate micronutrient intakes were assessed using the estimated average requirement (EAR) cut-point method. In both sexes, the prevalence rates of inadequacy for the majority of micronutrients were found to increase with age, being significantly higher in middle-aged adults and/ or post-menopausal women compared to children. Noteworthy findings of this study are that the prevalence rates of inadequate vitamin D and E intakes reached 100% and at least 75% across all gender and age groups, respectively. In addition at least 75% of women were found to have inadequate intakes of folate, and 75% of post-menopausal women were found to have inadequate intakes of calcium and magnesium. (Manios *et al.*, 2014).

Data from three studies conducted in Europe showed similar results. In one of those studies, data were obtained from the European Nutrition and Health Report II with 25 countries participating (Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, The Netherlands and The UK) and from LSE Europe Addition of Nutrients to Food Task Force Report (Roman Vinas *et al.*, 2011). In another study, researchers analyzed the adequacy of micronutrient intakes in several countries across Europe (Belgium, Denmark, France, Germany, the Netherlands, Poland, Spain and the UK) using national survey data (Mensink *et al.*, 2013). In the third study, researchers assessed nutrient intake and nutritional status of the general population of the United Kingdom (including Scotland, Wales and Northern Ireland) using the National Diet and Nutrition Survey that was conducted over a period 4 years (2008/2009-2011/2012) (National Diet and Nutrition Survey, 2014). Data from the three studies showed that intakes of minerals were of greater concern than those of vitamins. There were universal concerns for inadequate vitamin D intake where the prevalence rates of inadequacy (intake-below the EAR and the Lower Reference Nutrient Intake (LRNI) were remarkably high in all age and sex groups of different countries (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011). For vitamin E, inadequate intakes were reported in Belgium with more than 20% and 41% of girls aged 4-10 years having intakes below the LRNI and EAR, respectively (Mensink *et al.*, 2013). In addition, intakes of vitamin A below the LRNI were observed in British girls aged 11-18 years (National Diet and Nutrition Survey, 2014).

The prevalence rates of inadequacy for vitamin C (intake below the EAR) ranged from 10-20% in most countries except Spain Higher prevalence rates of vitamin C inadequacy ranging from 21-30% were found in Belgium (males), Denmark (males), Greece (adults), Sweden (adult females), and Finland (elderly females). In addition, prevalence rates of vitamin C inadequacy ranging from 31-40% were observed in Finland (males), Ireland (adults) and Sweden (adult males). The highest prevalence rates of vitamin C inadequacy (more than 40%) were seen in the UK (females and males except elderly males) (Roman Vinas *et al.*, 2011). Riboflavin intakes below the LRNI were noted in British girls (15%)

aged 11-18 years (National Diet and Nutrition Survey, 2014). Proportions for inadequacy for cobalamin were high for Poland (more than 5% of intakes below the LRNI) (Mensink *et al.,* 2013), Denmark (both genders and all age groups except adult females), Germany, Portugal, Spain, Sweden (adult males), the UK (adult females and elderly), Finland (adult males and elderly females) and Ireland (adult females) (Roman Vinas *et al.*, 2011).

The prevalence rates of calcium inadequacy (intake below the EAR and LRNI) were above 20% in most countries (National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011) with the highest percentage being in Poland among both genders and all age groups. Calcium intakes below the LRNI in the Polish population were 8% among children, 15% and 20% for girls and boys aged 4-10 years, respectively, >10% and >5% among girls and boys aged 11-17 years, respectively, 45% and 29% among women and men aged 18-60 years, respectively, and 55% and 48% among women and men aged >60 years, respectively (Mensink *et al.,* 2013). For potassium, intakes below the EAR were high and intakes below the LRNI exceeded 5%; reaching 31% with the highest proportions for Spain, France, the UK and Poland noting that the intakes below the EAR were higher for women (11-63%) compared to men (3-37%) (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014). There were also high proportions of subjects with intakes of magnesium below the LRNI in the UK among women aged 14-50 (26%), men aged 18-60 years (15%) and men >60 years (19%). Intakes below the EAR for magnesium were observed among women women aged 18-60 years (40%) and women and men aged >60 years (36% and 44%, respectively), intakes below the EAR were also observed among Polish and French women aged 18-60 years (25-27%), and among UK and French men aged 18-60 years (36% and 32%, respectively), and women and men >60 years (36% and 44%, respectively). Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014).

Mean intakes of folate were inadequate among all age and sex groups especially among girls and female adults. Mean intakes below the EAR increased with age ranging from 1% and less to 63% among Spanish girls aged 11-17 years, and 46% among women in The Netherlands (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011). Mean intakes of selenium were below the EAR, LRNI and the Reference Nutrient Intake (RNI) in almost all countries. Proportions of subjects with inadequate intakes of selenium were highest in France (36% of women, 31% of women and 14% of men aged >60 years had intakes below the LRNI; and 50% of women and 59% of men had intakes below the EAR). In Denmark, intakes of selenium were also insufficient (76% of women, 47% of men, 76% and 54% of women and men aged >60 years, respectively had intakes below the LRNI; and 85% and 90% of women and men had intakes below the EAR) (Mensink *et al.,* 2013), the UK (all age groups) (National Diet and Nutrition Survey, 2014), Sweden and Italy (at or >30% among elderly females) (Roman Vinas *et al.*, 2011). Iodine was a concern in several countries (Mensink *et al.*, 2013) such as Denmark, France, Germany, Poland and The UK including both genders and all age groups (Roman Vinas *et al.*, 2011). Inadequacy in iron intakes was observed among several countries especially among females in Denmark, France, Poland, the Netherlands and the UK (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011). Women among all countries had high percentages of iron intakes below the LRNI (25-50%) (Mensink *et al.*, 2013; Roman Vinas *et al.*, 2011). High prevalence of zinc inadequacy was observed in Ireland, Spain (elderly men), Germany (elderly females) with intakes below the EAR with >10% (Roman Vinas *et al.*, 2011). Zinc intakes in The UK were below the LRNI among both genders and all age groups (9%, 17% and 10% among children aged 4-10 years, children aged 11-18 years and 10% of men aged >65 years, respectively) (National Diet and Nutrition Survey, 2014). For copper, the prevalence of inadequacy was above 20% in Irish adult females and elderly men and female adults from the UK (Roman Vinas *et al.*, 2011).

Upon assessing micronutrient intakes among Central and Eastern European countries, comparisons of intakes with reference values suggest a high risk of vitamin D deficiency in all age groups, calcium deficiency among adults and children, and iron, folate and iodine deficiencies in children compared to other European countries (Novakovic et al., 2012).

In a study that aimed to evaluate micronutrient intakes compared to the RDA for different racial/ ethnic, gender and age groups among 4953 US adults with and without diabetes (Vaccaro and Huffman, 2013), results showed that Black non-Hispanics (BNH), females, older adults and people with diabetes had micronutrient insufficiencies. BNH, females, and people with diabetes were more likely to have insufficient calcium intakes. Among all the micronutrients tested (vitamin D, vitamin E, vitamin C, vitamin B12, folate, calcium, zinc, selenium, copper and iron), BNH persons were more likely to be deficient in all the micronutrients as compared to White non-Hispanics (WNH). Mexican-Americans (MA) were more likely to have inadequate intakes of vitamin E as compared to WNH. BNH and MA were more likely to be vitamin D and vitamin E deficient, respectively. BNH and older adults aged 65 years or more were more likely to be vitamin

B12 deficient. BNH and females tend to have lower intakes of copper compared to their counterparts. Females were more likely to be insufficient than males in all micronutrients tested except zinc which were not significantly different between the two gender groups. Persons with diabetes had insufficient intakes of selenium, zinc, calcium and folate as compared with those without diabetes (Vaccaro and Huffman, 2013). Micronutrients of public health concern in the US include vitamin D, calcium and potassium. Intakes of cobalamin, iron and folate are also of concern for specific age groups such as in adults 50 years and older and women childbearing age (U.S. Department of Agriculture, 2010).

Micronutrients intake in regional countries

A cross-sectional study conducted in Iran on 930 individuals aged ≥ 20 years showed that vitamin A deficiency was prevalent with 75% of the study population ingesting less than the recommended daily allowance (RDA) of 800 μg/ day and 25% receiving less than 400 μg/ day. In addition, 90-95% of subjects were receiving less than the minimum RDA of 10 μg/ day for vitamin D; and 50-75% had intakes less than the RDA of 800 mg/day for calcium (Ziaee *et al.,* 2012). Another cross-sectional study conducted on 1,111 Iranian individuals aged 20-80 years showed that 19.6% had mild vitamin D deficiency (20-30 ng/mL), 23.9% had moderate deficiency (10-20 ng/mL) and 26.9% had severe deficiency (<10 ng/mL) (Hovsepian *et al.,* 2011). In a third study conducted in Iran among 289 healthy females aged 18-28 years, 70%, 76% and 90% were found to have intakes of folate, iron and calcium lower than the RDA, respectively (Azadbakht and Esmaillzadeh, 2012). A forth study, conducted in a rural area (Rooran) and a suburban area (Khomeini) on 341 Iranian individuals including preschool children, school children, women and men showed that the prevalence of zinc deficiency was 5.9% in Rooran and 7.2% in Khomeini. Anemia associated with iron deficiency, however, was found to be more prevalent in Rooran (33.5%) than Khomeini (22.7%) (Abbaspour *et al.,* 2013). In addition, in a study conducted on an adult sample of 416 individuals in Shiraz, Southern Iran, the prevalence rate of copper deficiency was found to be 24% (Dabbaghmanesh *et al.,* 2011).

In Qatar, the prevalence of vitamin D deficiency in a study sample of 340 health care professionals showed that 97% and 87% of all participants had a mean level of 25(OH)D <30 ng/ml and <20 ng/ml, respectively. Results presented lower serum levels for females than that of males (Mahdy *et al.,* 2010).

Among 10,709 individuals in Saudi Arabia (68.5% of the studied population were Saudis and 31.5% were non-Saudis), the prevalence of vitamin D deficiency was found to be 83.6%, when cut points of <25, 50 and 75 nmol/l, for severe, moderate and mild deficiency were used, respectively. Severe deficiency was higher in females and adolescents as compared to their counterparts. Saudis were found to be more vitamin D deficient compared to non-Saudis (Hussain *et al.,* 2014).

A study conducted in Jordan on refugees coming from Iran, Iraq, Palestine and Sudan evaluated the nutritional status of 325 children aged 6 months – 10 years and 452 females aged 10 – 72 years. In this sample, prevalence rates of anemia, iron deficiency and vitamin A deficiency were found to be 75%, 64% and 28% in children and 45%, 44% and 6% in females, respectively (Khatib *et al.,* 2010).

In a sample of 2035 Jordanian women aged 15-49 years and 940 children aged 12-59 months old, prevalence of folate deficiency and insufficiency, anemia, iron deficiency and iron deficiency anemia in women and anemia, iron deficiency, and iron deficiency anemia in women and in children were assessed in 2002 and in 2010. Results from 2010 showed that the prevalence rates of folate deficiency, insufficiency, anemia, iron deficiency and iron deficiency anemia in women were found to be13.6%, 82.9%, 19.1%, 35.1% and 13.7%, respectively. In children in 2010, prevalence rates of anemia, iron deficiency and iron deficiency anemia were found to be 16.6%, 4.8% and 29.2% and respectively (Serdula *et al.,* 2014). In addition, in a sample of 564 Jordanian individuals aged 8 years and older, 32.2% showed to have vitamin B12 deficiency (El-Khateeb *et al.,* 2014).

Micronutrients intake in Lebanon

In a study sample of 470 Lebanese women of child bearing age, anemia, iron deficiency and iron deficiency anemia were found in 16%, 27.2% and 7.7%, respectively. In addition, plasma folate and cobalamin deficiencies were found to be 25.1% and 39.4%, respectively, and 12.6% of the women had both folate and vitamin B12 deficiencies (Al Khatib et al., 2006). Records from a large hospital laboratory database of 9147 participants, mostly outpatients from all age groups, showed that the prevalence of vitamin D deficiency (25(OH)D < 20 ng/mL) between 2007 and 2008. In 2008 prevalence of deficiency was 62%, 60% and 62% in pediatrics, adults and elderly, respectively. Prevalence of deficiency at a cut-off <30 ng/ml, was 78% in most sub-groups (Hoteit et al., 2014). In another study done in Lebanon among adolescents (n= 385, aged 10 to 161 years), only 16% met the Adequate Intake (AI) recommendation of

200 IU of vitamin D with no differences observed between the two gender groups. In addition, only 12% met the AI recommendations of 1300 mg of calcium (9.7% of girls and 15% of boys) (Salamoun *et al.,* 2005). A study conducted on 251 post-menopausal osteoporotic women aged 50 to 87 years, showed 85% of these women had vitamin D insufficiency with serum 25(OH)D <30 ng/ml (Gannage-Yared *et al.,* 2009). In addition, another study on vitamin D status in 316 Lebanese adults aged 30-50 years (99 men and 217 women), whereby 156 and 160 subjects were recruited from rural areas and urban areas, respectively, with 51 veiled women recruited from each area showed hypovitaminosis D [25(OH)D <12 ng/ml] to affect 72.8% of subjects (83.9% in women compared to 48.5% in men). Severe hypovitaminosis D [25(OH) D < 5 ng/ml] was perceived in 30.7% of participants and was more prevalent in women (41.5%) than men (7.1%), particularly among the veiled women (61.8%) compared with non-veiled women (23.5%), with 25(OH)D levels (5.12 ± 3.57 ng/ml vs. 9.80 ± 6.46 ng/ml, respectively; $p < 0.001$. Differences between rural and urban areas were also observed whereby 25(OH) D levels were found to be the lowest in women and highest in men living in rural areas. (Gannage-Yared, M *et al.,* 2000).

Consequences of insufficient and excess intakes of micronutrients

Micronutrients taken in quantities less than or in excess of the required amounts can cause specific diseases and can act as exacerbating factors in infectious and chronic diseases thereby, greatly impacting morbidity, mortality and quality of life. For example, vitamin A deficiency, which is very common among poor countries, causes anemia, growth retardation, increases the incidence and/or severity of infectious episodes and reduces childhood survival (Sommer and West, 1996) visual dysfunction leading to night blindness and xerophthalmia (WHO 1996). On the other hand, an excess of vitamin A may lead to adverse effects on bones (Feskanich *et al.*, 2002), liver damage, joint pain, alopecia, headache, vomiting and skin desquamation (Smith and Goodman, 1976). Whereas vitamin D deficiency can lead to hypocalcemia causing secondary hyperparathyroidism, which in turn leads to phosphaturia, demineralization of bones and with prolonged deficiency, osteomalacia in adults and rickets in children (Christakos *et al.* 2010), where excessive vitamin D doses lead to chronic intoxication which may cause bone demineralization and pain (Van Driel *et al.,* 2006). Vitamin B12 deficiency also appears to be associated with an increased risk appears to be associated with an increased risk of osteoporosis (Tangney *et al.,* 2009; Lindenbaum *et al.,* 1988) and hip and spine fractures (Kumar, 2006; Prodan *et al.,* 2007). Vitamin E deficiency is very rare, however if it exists it can result in peripheral neuropathy, spinocerebral ataxia, skeletal myopathy and increased erythrocyte fragility (Li *et al.,* 1999).

Scurvy which is the classic disease of severe vitamin C deficiency causes follicular hyperkeratosis, petechiae, ecchymoses, inflamed and bleeding gums, joint effusions, and arthralgia (Krebs *et al.*, 1948; McLaren, 1992). Large doses of vitamin C intake, on the other hand, can be associated with diarrhea and other gastrointestinal disturbances (Kubler and Gehler, 1970). Studies of thiamine deficiency showed its association with disorders such as wet and dry beriberi. Edema occurs in wet beriberi and is associated with fatal heart failure, whereas muscle wasting and peripheral neuropathy are associated with dry beriberi (McCormick, 1998a; McCormick, 1997). Severe thiamin deficiency can be linked to heavy alcohol consumption with limited amounts of food consumed; the result is Wernicke-korsakoff syndrome, a syndrome that can lead to life threatening renal and cardiovascular complications in severe cases (Pazirandeh *et al.,* 2014; McCormick and Greene, 1994). Riboflavin deficiency may result in symptoms such as weakness, mouth pain, burning eyes and itching. Advanced symptoms lead to dermatitis, cheilosis, angular stomatitis, brain dysfunction and microcytic anemia (McCormick, 1994). Riboflavin deficiency also decreases the absorption and utilization of iron for hemoglobin synthesis which makes it possible that the deficiency of riboflavin contributes to the high prevalence of anemia worldwide (Powers *et al.*, 1983). Deficiency in pyridoxine alone is uncommon; it usually exists in association with deficiencies of other B-complex vitamins (McCormick, 1998b). Symptoms of pyridoxine deficiency include seborrheic dermatitis, microcytic anemia, epileptiform convulsions, depression and confusion (IoM, 2006). Niacin deficiency results in pellagra which is characterized by pigmented rash, vomiting, constipation or diarrhea, bright red tongue, depression, apathy, fatigue, and memory loss (Pazirandeh *et al.,* 2014). Folate deficiency produces megaloblastic anemia (CDC, 1992; Geller *et al.,* 2002) and neurologic changes (Healton *et al.*, 1991).

Insufficient intakes of calcium result in reduced bone mineralization and an increased risk for osteoporosis in adults. Excessive intakes of calcium, however, can result in adverse effects including kidney stones, hypercalcemia and renal insufficiency, and reduce absorption of other minerals. Low phosphorus intakes, causing hypophosphatemia, can result in anorexia, anemia, muscle weakness, bone pain, rickets in children and osteomalacia in adults, increased susceptibility to infection, ataxia and possible death. However, hyperphosphatemia results in decreased calcium absorption and calcification of non-skeletal tissues especially the kidneys (IoM, 2006). Consequences of magnesium deficiency include anorexia, nausea, muscular weakness and lethargy and weight loss if deficiency is sustained (Shils, 1969; Shils, 1988). Progressive depletion of magnesium results in hyperirritability, hyperexcitability, muscular spasms and tetany leading to convulsions (Shils, 1988). Moderate potassium decline leads to elevated blood pressure, raised salt sensitivity, increased risk of kidney stones, elevated bone turnover, and possibly an increased risk of cardiovascular disease. Severe potassium deficiency (Hypokalemia) results in cardiac arrhythmias, muscle weakness and glucose intolerance. Excess sodium intake leads to elevated blood pressure which is related to cardiovascular and renal diseases (IOM, 2006).

Iron deficiency causes anemia, impaired cognitive and physical performance and increased maternal and child mortality (Brabin *et al.*, 2001a, Brabin *et al.*, 2001b, Brownlie *et al.*, 2002). Maternal iron deficiency can triple and double the risk of having a low birth weight and a premature baby, respectively (Scholl *et al.*, 1992) and deficiency in toddlers can lead to developmental delays which appear to be irreversible (Lozoff *et al.*, 1998; Walter, 1994). Excess iron intake, on the other hand, can cause adverse effects including vomiting and diarrhea, followed by cardiovascular, central nervous system, kidney, liver and hematological effects (IoM, 2006). Clinical manifestations of zinc deficiency may include dermatitis, retarded growth, diarrhea, mental disturbances and recurrent infections (Hambidge, 2000). Severe selenium deficit is associated with skeletal muscle dysfunction and cardiomyopathy (Rayman, 2000; Finley and Penland, 1998) and may also cause mood disorders and impaired immune function (Sappey *et al.*, 1994; Taylor *et al.*, 1997) as well as macrocytosis and Keshan disease (Ishida *et al.*, 2003). Excess intake of selenium, however, may cause hair and nail brittleness and loss, gastrointestinal disturbances, skin rash, garlic breath odor, fatigue, irritability and nervous system abnormalities (IoM, 2006). Copper deficiency is often rare; however, if it exists symptoms include normocytic hypochromic anemia, leukopenia, neutropenia and osteoporosis (in copper deficient children).

In Lebanon and according to a report published by Unicef (2014), each year a total of 150 Lebanese infants are at risk of death in the period directly before or after birth and about 100 severe birth defects occur, including infantile paralysis, due to anemia and folate deficiency in mothers during pregnancy, respectively. In addition, an estimated 7000 Lebanese babies are born every year with intellectual impairment caused by iodine deficiency in pregnancy. Approximately 20% of the children in Lebanon are growing up with lowered immunity due to micronutrient deficiencies, such as the deficiency of vitamin A (Unicef, 2014).

It is clear from what has been enumerated that it is critical to examine the dietary intakes of people in different age groups, given the growing body of evidence on the role of micronutrient deficiencies/ escesses in causing some diseases and possibly death (Shenkin, 2006). Within the population, there are certain age groups that are more prone to poor or inadequate intake of certain micronutrients such as adolescents and teenagers who may have insufficient intakes of milk and other calcium containing food sources (Zalewski *et al.*, 1991). In addition, elderly in nursing homes and residential care centers may have poor intakes of vitamin D as well as zinc, iron, vitamin C and riboflavin (Finch *et al.*, 1998). Moreover, certain groups of people have increased requirements of certain micronutrients such as pregnant women who need to increase folate intake before conception and in the first trimester (IOM, 1998b). Smokers are another group of people who require increased supplies of vitamin C (IOM, 2000).

Unhealthy dietary habits and improper intakes of micronutrients may start in childhood, adolescence or early adulthood, not only affecting the general state of health in these years, but also resulting in long-term serious health effects in later adulthood (Moore *et al.*, 2012). Over the last few decades, social and lifestyle changes together with lack of nutritional knowledge and awareness have either caused people in Lebanon to follow self-administered vegetarian, low calorie diets (particularly females) or increase their intake of low-cost, energy-dense foods known as the "Westernized diets" (James 2008; Salameh *et al.*, 2014). Adoption of "Westernized diets" by people in Lebanon has, in turn, caused many beneficial and necessary foods , such as fruits, vegetables and fish, to be consumed in amounts less than the recommended amount whereas, it has caused harmful foods, such as fat, to contribute more to daily energy intake (Nasreddine *et al.*, 2006). This, in turn can cause deficiencies of micronutrients and put the Lebanese population at increased risk of developing diseases. In addition, imbalances in the proportions of macronutrients can also increase the risk of chronic diseases and may harmfully affect micronutrients intake. Multiple national epidemiological surveys performed in several developing countries, for example, have reported the coexistence of obesity with inadequate intakes of certain vitamins and minerals including vitamin D, vitamin B1, vitamin B2, vitamin B6, folate, calcium, iron and zinc (Hallberg 1995; Brussard *et al*, 1999; Elmadfa *et al*, 2009; Harvey *et al*, 2013). Not only micronutrient deficiencies but also excesses have adverse effects (IoM, 1998a).

Optimizing the nutritional status of the populations is one of the primary responsibilities of dietitians, health care providers and public health authorities. Lebanon lacks sufficient data on intakes of micronutrients, resulting in incomplete information related to vitamin and mineral deficiencies and excesses. It is thus of crucial importance to have comprehensive data on micronutrient intakes of people in Lebanon of different age and gender groups, especially adults since they tend to follow unhealthy eating patterns, in order to identify health concerns, associated with micronutrient deficiencies/excesses, in the Lebanese population and then design and implement interventions to control these concerns. Interventions to ensure the consumption of the recommended amounts of micronutrients could include fortifying certain essential foods like flour with vitamins and minerals, especially that there are no policies adopted in Lebanon regarding food fortification, or supplementing individuals at risk of developing deficiencies and those with deficiencies. Interventions could also include awareness campaigns related to adverse health problems associated with vitamin and mineral deficiencies and excesses. The current study aims to quantify and compare the dietary intakes of various micronutrients to recommended micronutrient intakes, in order to identify dietary micronutrients deficiencies and excesses among a sample of Lebanese adults.

METHODOLOGY

Study design and population

This was a cross-sectional study conducted between 2009 and 2011 on a random sample of 615 (232 males and 383 females) Lebanese adults aged 19-70 years living in different casas in Lebanon (Batroun, Beirut, Jbeil, Jezzine, Keserwan, Metn and Shouf). In order to encompass individuals living in different regions in each casa, participants were randomly selected through door-to-door visits from 5 different towns in each casa. Participants were selected if they were Lebanese, did not have any chronic diseases, did not follow specific diets, their daily caloric intake was between 800 and 5000 Kcal per day, are neither pregnant nor lactating and did not take any type of supplements.

Data collection

Dietary intake was assessed using the US National Institute of Health (NIH) diet history questionnaire, a quantitative web-based food frequency questionnaire (FFQ) composed of 144 questions detailing the consumption of different foods, beverages and dietary supplements, portion sizes and consumption frequency over the past year. A sample of the FFQ is available online (NCI-NIH, 2007). Each participant completed the questionnaire during a one-on-one meeting with a trained nutrition research assistant to ensure the understanding of the questions and measurement units, and to ensure the appropriate selection of food items that are culture-specific. In addition, photos of the servings were employed to facilitate estimations. Questions were translated to Arabic the mother tongue language for interviewees. A total of 759 participants completed the questionnaire, out of which 144 were excluded from the final analysis due to incomplete questionnaires and out of range energy intakes. The collected data were uploaded on the NIH web-based diet history questionnaire utility, retrieved and analyzed for nutrient composition using NIH Diet*Calc software, version 1.4.3.

Identity of the subjects remained anonymous and confidential. Computerized data were stored on a password protected computer in a locked office of the research team and all research files are maintained in a locked cabinet in the principal investigator's office. Data were entered and checked to ensure that typographical or other errors in data files are corrected; duplicate entries were monitored as data were transferred from Diet*Calc to SPSS.

Comparison with nutritional guidelines

To assess status of micronutrient intakes, gender- and age- specific dietary reference values established by the Food and Nutrition Board of the Institute of Medicine (IOM) were used: Estimated Average Requirement (EAR) in the case of vitamin A, vitamin D, Vitamin E, Vitamin C, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, calcium, phosphorus, magnesium, selenium, copper, iron and zinc, and Adequate Intake (AI) in the case of potassium and sodium because dietary reference intakes for these two minerals include only AI. Nutrient intakes exceeding the EAR were also compared to Tolerable Upper Intake Level (UL), which is also a dietary reference value established by the IOM.

Dietary Reference Intakes (DRIs): Estimated Average Requirements:

Food and Nutrition Board, Institute of Medicine, National Academics

Life stage group	Vitamin A (μg/d)	Vitamin C (mg/d)	Vitamin D (μg/d)	Vitamin E (mg/d)	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)	Vitamin B6 (mg/d)	Vitamin B12 (μg/d)
Males									
19-30 y	625	75	10	12	1	1.1	12	1.1	2
31-50 y	625	75	10	12	1	1.1	12	1.1	2
51-70 y	625	75	10	12	1	1.1	12	1.4	2
Females									
19-30 y	500	60	10	12	0.9	0.9	11	1.1	2
31-50 y	500	60	10	12	0.9	0.9	11	1.1	2
51-70 y	500	60	10	12	0.9	0.9	11	1.3	2

Life stage group	Folate (μg/d)	Calcium (mg/d)	Copper (μg/d)	Iron (mg/d)	Magnesium (mg/d)	Phosphorus (mg/d)	Selenium (mg/d)	Zinc (mg/d)
Males								
19-30 y	320	800	700	6	330	580	45	9.4
31-50 y	320	800	700	6	350	580	45	9.4
51-70 y	320	800	700	6	350	580	45	9.4
Females								
19-30 y	320	800	700	8.1	255	580	45	6.8
31-50 y	320	800	700	8.1	265	580	45	6.8
51-70 y	320	1000	700	5	265	580	45	6.8

Dietary Reference Intakes (DRIs): Adequate Intakes:

Food and Nutrition Board, Institute of Medicine, National Academics

Life stage group	Potassium (g/d)	Sodium (g/d)
Males		
19-30 y	4.7	1.5
31-50 y	4.7	1.5
51-70 y	4.7	1.3
Females		
19-30 y	4.7	1.5
31-50 y	4.7	1.5
51-70 y	4.7	1.3

Dietary Reference Intakes (DRIs): Tolerable Upper Intake Levels:

Food and Nutrition Board, Institute of Medicine, National Academics

Life stage group	Vitamin A (μg/d)	Vitamin C(mg/d)	Vitamin D (μg/d)	Vitamin E (mg/d)	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)	Vitamin B6(mg/d)	Vitamin B12 (μg/d)
Males									
19-30 y	3,000	2,000	100	1,000	ND	ND	35	100	ND
31-50 y	3,000	2,000	100	1,000	ND	ND	35	100	ND
51-70 y	3,000	2,000	100	1,000	ND	ND	35	100	ND
Females									
19-30 y	3,000	2,000	100	1,000	ND	ND	35	100	ND
31-50 y	3,000	2,000	100	1,000	ND	ND	35	100	ND
51-70 y	3,000	2,000	100	1,000	ND	ND	35	100	ND

Life stage group	Folate (µg/d)	Calcium (mg/d)	Copper (µg/d)	Iron (mg/d)	Magnesium (mg/d)	Phosphorus (mg/d)	Selenium (mg/d)	Zinc (mg/d)	Sodium (g/d)
Males									
19-30 y	1,000	2,500	10,000	45	350	4	400	40	2.3
31-50 y	1,000	2,500	10,000	45	350	4	400	40	2.3
51-70 y	1,000	2,000	10,000	45	350	4	400	40	2.3
Females									
19-30 y	1,000	2,500	10,000	45	350	4	400	40	2.3
31-50 y	1,000	2,500	10,000	45	350	4	400	40	2.3
51-70 y	1,000	2,000	10,000	45	350	4	400	40	2.3

Statistical analysis

Dietary data are reported using descriptive statistics. Means and standard deviations/ medians with interquartile ranges to describe continuous normally / non-normally distributed variables were calculated, respectively. Counts are percentages and were used to describe categorical variables. Independent-Samples T-Test / Mann-Whitney *U* test was used to compare mean daily calorie intake between males and females in early adulthood (19 and 30 years old), mid-adulthood (31 and 50 years) and late adulthood (51-70 years), respectively. Age groups were divided according to the tables adopted by the DRI. The Independent-Samples T-Test was used to compare means of daily micronutrient intake between males and females whenever the variable that represent micronutrient intake was normally distributed, whereas the non-parametric test of Mann-

Whitney *U* test was whenever the variable was non-normally distributed. Means of daily micronutrients intakes were compared across the three different age groups, separately for males and females using the Kruskal-Wallis test. Means of daily micronutrient intakes were compared to the IOM Dietary References Intakes (DRI) in males and females by age groups using the one-sample *t*-test. Analyses were done using SPSS version 20 (SPSS Inc, Chicago, IL, USA) and the level of significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Means of daily caloric intakes of males and females by early, mid and late adulthood are presented in Table I. In all age groups, males had a significantly higher mean daily calories intake than females (3023±1473 vs. 2276±1125, 3061±1477 vs. 2393±1131 and 2991±1456 vs. 2047±1004 in their early adulthood, mid-adulthood and late adulthood, respectively. Intakes of vitamins and minerals of males and females among the different age groups were not compared because males had higher energy intake than females and thus intakes of vitamins and minerals were higher.

Table I. Mean daily caloric intake in Males and Females by age group

Age group	Female (n=383)		Male (n=232)		*P*- value*
	%	Daily caloric intake (Mean±SD)	%	Daily caloric intake (Mean± SD)	
19-30	220 (57.4%)	2276 ±1125	150 (64.6%)	3023 ±1473	<0.001
31-50	138 (36.0%)	2393 ±1131	67 (28.9%)	3061 ±1477	<0.01
51-70	25 (6.6%)	2047 ±1004	15 (6.4%)	2991 ±1456	<0.01

**p*-value represents difference on mean daily caloric intake between males and females

The means of daily micronutrient intakes of adult Lebanese males and females are presented in Table II. Mean Intake of 17 out of the 19 studied micronutrients differed between the two genders. With the exception of Vitamins A and C, males had significantly higher intakes of vitamin D, vitamin E, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, calcium, phosphorus, magnesium, potassium, sodium, copper and iron than females. This difference in intake could be related to having higher energy consumption. Since males consumed more calories per day compared to females, it is expected to have a higher intake of micronutrients as well.

Table II. Mean daily intake of micronutrients in adult Lebanese males and females

Micronutrient	Female (n=383) Mean±SD	Male (n=232) Mean±SD	*P*- value*
Vitamin A (µg)	1598.44 ±1269.98	1761.93 ±1259.87	0.12
Vitamin D (µg)	3.75 ±3.14	4.92±3.51	<0.001
Vitamin E (mg)	13.46 ±7.90	15.97 ±10.35	0.002
Vitamin C (mg)	174.97 ±154.67	198.47 ±142.02	0.06
Thiamin (mg)	1.72±0.88	2.13 ±1.08	<0.001
Riboflavin (mg)	1.98 ±1.00	2.5 ±1.23	<0.001
Niacin (mg)	23.93 ±11.95	31.78 ±05	<0.001
Vitamin B6 (mg)	2.17 ±1.22	2.70 ±1.37	<0.001
Folate (µg)	457.38 ±236.84	533.23 ±271.52	<0.001
Vitamin B12 (µg)	5.80 ±7.39	8.13 ±6.14	<0.001
Calcium (mg)	849.57 ±444.01	1026.66 ±523.70	<0.001
Phosphorus (mg)	1378.71 ±675.66	1743.48 ±856.27	<0.001
Magnesium (mg)	377.13 ±185.90	448.00 ±217.25	<0.001
Potassium (g)	3956.48±2048.73	4584.14 ±2291.19	<0.001
Sodium (g)	3667.29 ±1854.47	4511.03 ±2437.46	<0.001
Copper (mg)	1.82 ±1.00	2.20 ±1.17	<0.001
Iron (mg)	16.11 ±7.75	20.06 ±10.23	<0.001
Selenium (µg)	110.03 ±57.79	148.96 ±83.81	<0.001
Zinc (mg)	11.99 ±6.47	16.31 ±9.77	<0.001

**p*-value using independent sample student t-test

Table III and Table IV present results pertaining to differences in means of daily micronutrient intakes among subjects in early, mid and late for males and females, respectively. No significant differences in daily vitamin and mineral intakes across the 3 different age groups (19-30, 31-50 and >50 years old) were found in males except for magnesium and potassium. Subjects in mid and late adulthood were found to have significantly higher mean daily magnesium intake than subjects in early adulthood (390.69 (early adulthood); 450.87 (mid adulthood) and 469.9 mg (late adulthood), p=0.04. An increase in mean daily potassium intake from 3839.68 g in early adulthood to 4828.64 g in mid-adulthood was observed then intake decreased to 4487 g in late adulthood with a significant difference between subjects in early and mid-adulthood (p = 0.014) (Table III). This increase in potassium intake is linked to the increased intake of fruits and vegetables among males in their fifties who reported higher intakes of fruits and vegetables (Leblanc *et al.*, 2014). In females, mean daily magnesium intake increased with age from 315.54 mg in early adulthood to 380.55 mg in mid-adulthood then decreased to 355.7 mg in late adulthood with a significant difference between the means of daily magnesium intake of early and mid-adults (p = 0.004). An increase in mean daily potassium intake from 3184.69 g in early adulthood to 3946.49 in mid-adulthood and a decrease to 3783 g in late adulthood was also observed, with a significant difference between the means of daily potassium intake of early adults and mid-adults (p <0.001). Similar patterns were observed for vitamin A, vitamin C, vitamin B12 and copper where intakes increased from early adulthood to mid-adulthood and then decreased in late adulthood. There was a significant difference in the mean daily intake of vitamin A between early (1151.18 μg) and mid-adults (1589.58 μg) (p = 0.001) and between mid-adults (1589.58 μg) and late adults (1290 μg) (p = 0.01). A significant difference was also noted in the mean daily intake of vitamin C between early (116.03 mg) and mid-adults (175.05 mg) (p <0.001), early (116.03 mg) and late adults (144.3 mg) (p = 0.01) and mid (175.05 mg) and late adults (144.3 mg) (p = 0.02). Differences in the means of daily intake of vitamin B12 and copper were significant between mid (4.57 μg) and late adults (3.29 μg) (p = 0.01), and between early (1.47 mg) and mid-adults (1.78 mg) in the intakes of copper (p =0.007). This could be due to alterations in food choices, preferences and/ or availability. Food choices and preferences may differ among individuals according to factors such as demographic (age), biological, economic, physical, and social and psychological determinants. Appetite for instance may weaken with age which explains the reduced intake of certain vitamins and minerals among subjects in late adulthood. In a study studying the factors affecting food selection among Canadians, factors including education, income, gender, physical activity and age have shown to play a role in selecting or evading certain foods (Ree *et al.*, 2008).

Table III. Median daily intake of micronutrients in males by age group

	Age 19-30 years (n=150) Median (IQR)	Age 31-50 years (n=67) Median (IQR)	Age 51-70 years (n=15) Median (IQR)	*P*-value*
Vitamin A (μg)	1376.44 (724.5-2350.65)	1848.3 (1021.12-2759.6)	1473(560-2188)	0.07
Vitamin D (μg)	4.34 (2.08-7.04)	4.19 (2.46-6.57)	3.84 (1.64-5.77)	0.32
Vitamin E (mg)	14.07 (7.89-19.98)	16.36 (8.96-22.79)	15.3 (8.6-19.4)	0.40
Vitamin C (mg)	149.22 (82.19-265.68)	198.85 (116.0-313.02)	136.5 (89.0-252.3)	0.05
Thiamin (mg)	1.97 (1.15-2.81)	2.1 (1.29-2.93)	1.54 (1.15-2.25)	0.19
Riboflavin (mg)	2.46 (1.4-3.36)	2.32 (1.58-3.57)	1.05 (1.42-2.44)	0.30
Niacin (mg)	27.89 (17.27-42.73)	30.46 (22.18-43.59)	27.32 (15.7-34.7)	0.29

Vitamin B6 (mg)	2.57 (1.43-3.6)	2.8 (1.79-3.87)	2.08 (1.62-2.82)	0.09
Folate (μg)	460.83 (282.15-739.54)	575.26 (365.84-772.17)	433.44 (287.53-655.52)	0.09
VitaminB12 (μg)	6.51 (3.09-10.71)	7.58 (3.72-13.35)	6.18 (2.50-8.59)	0.24
Calcium (mg)	927.01 (610.77-1371.8)	937.96 (641-1364.83)	839.3 629.6-1238.5)	0.65
Phosphorus (mg)	1628.35 (1021.6-2365.81)	1676.57 (1097.95-2270.61)	1605 (850-1944)	0.38
Magnesium (mg)	**390.69 (243.61-566.67)**	**450.87 (344.54-632.3)**	**469.9 (264.8-511.5)**	**0.04**
Potassium (g)	**3839.68 (2494.8-5819.35)**	**4828.64 (3618.13-6954.82)**	**4487 (3205-5207)**	**0.014**
Sodium (g)	4037.76 (2710.73-6001.69)	3926.26 (2735.24-6177.72)	3325 (2129-4889)	0.27
Copper (mg)	1.96 (1.16-2.97)	2.38 (1.37-3.33)	1.87 (1.07-1.87)	0.15
Iron (mg)	18.24 (11.03-25.93)	19.84 (14.47-27.99)	15.19 (10.41-23.92)	0.11
Selenium (μg)	129.98 (82.48-194.96)	145.68 (87.9-205.82)	125.4 (68.9-168.4)	0.42
Zinc (mg)	13.28 (8.27-22.90)	15.08 (10.57-22.58)	12.6 (6.2-16.0)	0.19

IQR: interquartile range

**p*-value from Kruskal-Wallis test

Table IV. Mean daily median intake of micronutrients in females by age groups

	Age 19-30 years (n=220) Median (IQR)	Age 31-50 years (n=138) Median (IQR)	Age 51-70 years (n=25) Median (IQR)	*P*-value*
Vitamin A (μg)	**1151.18 (752.1-1882.77)**	**1589.58 (920-2232.36)**	**1290 (891-1680)**	**0.002**
Vitamin D (μg)	3.11 (1.77-5.10)	2.69 (1.54-4.83)	1.83 (1.33-4.03)	0.06
Vitamin E (mg)	11.27 (8.02-15.92)	12.36 (8.52-18.01)	9.7 (7.7-12.6)	0.14
Vitamin C (mg)	**116.03 (74.61-194.45)**	**175.05 (105.82-253.67)**	**144.3 (91.3-265.3)**	**<0.001**
Thiamin (mg)	1.46 (1.06-2.09)	1.59 (1.16-2.36)	1.42 (0.97-1.77)	0.17
Riboflavin (mg)	1.63 (1.23-2.39)	1.85 (1.33-2.78)	1.66 (1.06-1.99)	0.11
Niacin (mg)	20.84 (14.8-28.94)	21.8 (16.38-33.02)	20.18 (15.19-25.69)	0.17
Vitamin B6 (mg)	1.82 (1.22-2.63)	1.94 (1.38-2.98)	1.71 (1.38-2.48)	0.14

Folate (μg)	390.59 (277.14-540.56)	435.53 (326.17-607.49)	344.61 (306.88-503.38)	0.05
Vitamin B12 (μg)	3.95 (2.33-6.14)	**4.57 (2.78-8.67)**	**3.29 (2.49-6.34)**	**0.024**
Calcium (mg)	761.96 (512.15-1041.15)	762.3 (544.64-1157.11)	657.5 (497.6-936.3)	0.43
Phosphorus (mg)	1187.59 (900.66-1681.2)	1291.91 (907.76-1766.1)	1177 (711-1239)	0.30
Magnesium (mg)	**315.54 (221.73-448.55)**	**380.55 (268.15-504.7)**	355.7 (274.7-416.3)	**0.004**
Potassium (g)	**3184.69 (2295.22-4570.3)**	**3946.49 (2928.71-5690.88)**	3783 (2502-4343)	**<0.001**
Sodium (g)	3169.09 (2369.82-4362.55)	3507.05 (2457.5-4846.78)	2680 (1945-3797)	0.13
Copper (mg)	**1.47 (1.02-2.1)**	**1.78 (1.19-2.65)**	1.53 (1.11-2.13)	**0.007**
Iron (mg)	13.61 (10.12-19.76)	15.26 (11.25-21.16)	13.57 (10.16-17.06)	0.12
Selenium (μg)	99.1 (70.13-136.78)	94.86 (73.39-143.19)	83.0 (66.1-120.4)	0.57
Zinc (mg)	10.1 (6.7-14.68)	11.1 (7.91-16.77)	9.81(6.91-12.64)	0.25

IQR: interquartile range

**p*-value from Kruskal-Wallis test

In males of all age groups, the daily consumption of almost all vitamins and minerals (vitamin A, vitamin C, thiamin, niacin, vitamin B6, vitamin B12, phosphorus, magnesium, sodium, copper, iron, selenium and zinc) were found to be significantly higher than the EAR with intakes of all these vitamins and minerals being below the UL except for intakes of magnesium and sodium (Table V). Intakes of magnesium were shown to be higher than the UL in 55.3%, 74.6% and 73.3% of early, mid and late male adults, respectively and 82.7%, 80.6% and 83.3% of early, mid and late male adults, respectively, had intake of sodium exceeding the UL (Table V, Table VIII). Vitamin E, folate and calcium intakes were found to be significantly higher than the EAR among early and mid-adults without exceeding the UL (Table V). Potassium intakes were shown to exceed the AI among males in mid-adulthood but were shown to be lower than the AI among early and late male adults (Table V). Among the mid-adults age group, 47.8% had an intake of potassium that exceeded the AI (Table IX). Vitamin D levels were found to be lower than the EAR among males in all age groups and riboflavin intakes were lower than the EAR among late adult men (Table V). Ninety percent, 92.5% and 100% of early, mid and late male adults had insufficient intakes of vitamin D, respectively; and 6.7% of late adult males had insufficient intake of riboflavin (Table VII).

Similar to the results observed in males, in females of all age groups the daily consumption of almost all vitamins and minerals (Vitamin A, Vitamin C, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, copper, iron, phosphorus, selenium and zinc) was found to be significantly higher than the EAR but lower than the UL (Table VI). Vitamin E daily intakes were shown to exceed the EAR among early and mid-adult females but not the UL; however, intakes were below the EAR among late adult females but not significant (Table VI). Intakes of magnesium and sodium were also found to be significantly higher than the EAR and AI, respectively, and were shown to exceed the UL as well (Table VI). Magnesium intakes exceeded the UL among 39.5%, 58.7% and 52% of early, mid and late female adults, respectively; and 87.3%, 89% and 68% of early, mid and late female adults, respectively, had intakes of sodium that exceeded the UL (Table XI). Vitamin D daily intake was shown to be significantly lower than the EAR among all female age groups. Calcium was found to be lower than the EAR among late adult females (Table VI). Ninety-four percent, 97% and 96% of early, mid and late female adults had inadequate intakes of vitamin D, respectively; and 80% of late female adults had insufficient intakes of calcium (Table X). Potassium daily intakes were shown to be lower than the AI among adult females of all age groups, but only significant for early and late adult females (Table VI). Inadequate intakes of potassium ranged among 78.6%, 63.8% and 80% of early, mid and late adult females, respectively (Table XII).

Inadequate intake of vitamin D was observed in males and females of all age groups. Vitamin D deficiency is related to increased risk of developing osteoporosis (Love, 2002), cardiovascular diseases (Norman and Powell, 2014), type II diabetes (Xuan *et al.*, 2013) and probably cancer (Walentowicz-Sadlecka *et al.*, 2013). In the case of minerals, calcium intakes were found to be below the EAR among late adult women. Increased intake of dietary calcium can increase total body and lumbar spine bone mineral content (Huncharek *et al.*, 2008). These findings indicate inadequate intake of milk and dairy products among women aged 51-70 years old. In addition, these findings taken together indicate high risk of osteoporosis among late adulthood. Inadequate intake of potassium observed among all women and among early and late adult men is also a concern since sufficient intake of potassium is a key dietary factor in prevention of hypertension (Koliaki and Katsilambros, 2013). This concern is validated by the excessive sodium intake, another risk factor for hypertension, observed among all age groups of both genders (Koliaki and Katsilambros, 2013). Excess sodium intakes especially among late adults could be due to having weakened senses and losing the sensitivity to salty and bitter tastes, leading people to add more salt than at earlier ages. Adequate intakes of these minerals may also be important in osteoporosis prevention, since adequate potassium intake exerts protective effect against age-related bone loss (Weave, 2013), while high sodium intake increases the loss of urinary calcium (Atkinson and Ward, 2001). Our study showed that intakes of magnesium exceed the UL among both males and females of all age groups; magnesium intakes has been negatively associated with insulin resistance, type II diabetes, hypertension, cardiovascular disease and metabolic syndrome; and positively associated with bone mass (Rosanoff *et al.*, 2012).

Table V. Comparison of daily micronutrient intake in males to the IOM dietary reference intakes

	Age 19-30 years (n=150) Mean (SD)***	*P*-value*	Age 31-50 years (n=67) Mean (SD)***	*P*-value*	Age 51-70 years (n=15) Median (IQR)***	*P*-value**
Vitamin A (µg)	**1643.38 (1183.50)**	**<0.001**	**2053 (1401)**	**<0.001**	**1473(560-2188)**	**0.005**
Vitamin D (µg)	**5.06 (3.65)**	**<0.001**	**4.92 (3.42)**	**<0.001**	**3.84 (1.64-5.77)**	**<0.001**
Vitamin E (mg)	**15.80 (11.18)**	**<0.001**	**16.80 (9.11)**	**<0.001**	15.3 (8.6-19.4)	0.42
Vitamin C (mg)	**187.07 (141.75)**	**<0.001**	**229.96 (148.32)**	**<0.001**	**136.5 (89.0-252.3)**	**0.005**
Thiamin (mg)	**2.11 (1.09)**	**<0.001**	**2.27 (1.09)**	**<0.001**	**1.54 (1.15-2.25)**	**0.01**
Riboflavin (mg)	**2.48 (1.23)**	**<0.001**	**2.64 (1.25)**	**<0.001**	1.05 (1.42-2.44)	0.44
Niacin (mg)	**31.18 (16.30)**	**<0.001**	**34.01 (15.71)**	**<0.001**	**27.32 (15.7-34.7)**	**<0.001**
Vitamin B6 (mg)	**2.65 (1.37)**	**<0.001**	**2.95 (1.42)**	**<0.001**	**2.08 (1.62-2.82)**	**0.013**
Folate (µg)	**517.48 (269.53)**	**<0.001**	**591.03 (280.43)**	**<0.001**	433.44 (287.53-655.52)	0.07
Vitamin B12 (µg)	**7.68 (5.77)**	**<0.001**	**9.14 (6.46)**	**<0.001**	**6.18 (2.50-8.59)**	**0.003**
Calcium (mg)	**1056.32 (517.34)**	**<0.001**	**1056.32 (517.35)**	**<0.001**	839.3 (629.6-1238.5)	0.46
Phosphorus (mg)	**1743.93 (863.78)**	**<0.001**	**1810.76 (873.33)**	**<0.001**	**1605 (850-1944)**	**0.001**
Magnesium (mg)	**420.46 (206.41)**	**<0.001**	**509.40 (233.23)**	**<0.001**	**469.9 (264.8-511.5)**	**<0.001**
Potassium (g)	**4250.82 (2125.52)**	**0.011**	**5356.90 (2548.36)**	**0.04**	4487 (3205-5207)	0.42
Sodium (g)	**4563.15 (2443.57)**	**<0.001**	**4633.32 (2546.37)**	**<0.001**	**3325 (2129-4889)**	**0.001**
Copper (mg)	**2.09 (1.12)**	**<0.001**	**2.45 (1.25)**	**<0.001**	**1.87 (1.07-1.87)**	**0.001**
Iron (mg)	**19.76 (10.48)**	**<0.001**	**21.63 (9.97)**	**<0.001**	**15.19 (10.41-23.92)**	**<0.001**
Selenium (µg)	**147.95 (86.61)**	**<0.001**	**156.06 (81.19)**	**<0.001**	**125.4 (68.9-168.4)**	**0.001**

Zinc (mg)	**16.07 (9.76)**	**<0.001**	**17.51 (9.86)**	**<0.001**	**12.6 (6.2-16.0)**	**0.001**

***SD: Standard Deviation, IQR: interquartile range

**p*-value from one-sample t-test

***p*-value from Mann-whitney test

Table VI. Comparison of daily micronutrient intake in females to the IOM dietary reference intakes

	Age 19-30 years (n=220) Mean (SD)***	*P*-value*	Age 31-50 years (n=138) Mean (SD)***	*P*-value*	Age 51-70 years (n=25) Median (IQR)***	*P*-value**
Vitamin A (μg)	**1488.28 (1310.55)**	**<0.001**	**1820.03 (1259.68)**	**<0.001**	**1290 (891-1680)**	**0.02**
Vitamin D (μg)	**4.03**	**<0.001**	**3.47 (2.60)**	**<0.001**	**1.83 (1.33-4.03)**	**<0.001**
Vitamin E (mg)	**13.24 (8.36)**	**0.03**	**14.08 (7.20)**	**0.01**	9.7 (1.1-12.6)	0.15
Vitamin C (mg)	**152.04 (117.60)**	**<0.001**	**208.77 (198.06)**	**<0.001**	**144.3 (91.3-265.3)**	**<0.001**
Thiamin (mg)	**1.68 (0.87)**	**<0.001**	**1.80 (0.88)**	**<0.001**	**1.42 (0.97-1.77)**	**<0.001**
Riboflavin (mg)	**1.94 (1.02)**	**<0.001**	**2.09 (0.99)**	**<0.001**	**1.66 (1.06-1.99)**	**<0.001**
Niacin (mg)	**23.41 (12.36)**	**<0.001**	**25.00 (11.34)**	**<0.001**	**20.18 (15.19-25.69)**	**<0.001**
Vitamin B6 (mg)	**2.10 (1.24)**	**<0.001**	**2.30 (1.21)**	**<0.001**	**1.71 (1.38-2.48)**	**0.02**
Folate (μg)	**436.27 (217.53)**	**<0.001**	**495.73 (264.07)**	**<0.001**	**344.61 (306.88-503.38)**	**0.03**
Vitamin B12 (μg)	**5.60 (8.81)**	**<0.001**	**6.36 (5.13)**	**<0.001**	**3.29 (2.49-6.34)**	**<0.001**
Calcium (mg)	827.42 (414.42)	0.33	894.63 (490.11)	0.25	**657.5 (497.6-936.3)**	**0.021**
Phosphorus (mg)	**1378.29 (681.47)**	**<0.001**	**1409.58 (676.17)**	**<0.001**	**1177 (711-1239)**	**<0.001**
Magnesium (mg)	**353.91 (178.25)**	**<0.001**	**415.52 (195.58)**	**<0.001**	**355.7 (274.7-416.3)**	**<0.001**
Potassium (g)	**3597.50 (1879.83)**	**<0.001**	4519.30 (2224.00)	0.34	**3783 (2502-4343)**	**0.017**
Sodium (g)	**3613.09 (1828.93)**	**<0.001**	**3820.47 (1876.37)**	**<0.001**	**2680 (1945-3797)**	**<0.001**

Copper (mg)	**1.72 (0.99)**	**<0.001**	**2.01 (1.01)**	**<0.001**	**1.53 (1.11-2.13)**	**<0.001**
Iron (mg)	**15.77 (7.93)**	**<0.001**	**16.87 (7.44)**	**<0.001**	**13.57 (10.16-17.06)**	**<0.001**
Selenium (µg)	**112.16 (62.31)**	**<0.001**	**109.15 (52.65)**	**<0.001**	**83.0 (66.1-120.4)**	**<0.001**
Zinc (mg)	**11.75 (6.58)**	**<0.001**	**12.55 (6.37)**	**<0.001**	**9.81(6.91-12.64)**	**0.001**

***SD: Standard Deviation, IQR: interquartile range

**p*-value from one-sample t-test

***p*-value from Mann-whitney test

Table VII. Percentage of males having a mean intake below the EAR

	Age 19-30 years (n=150)	Age 31-50 years (n=67)	Age 51-70 years (n=15)
Vitamin D (µg)	90%	92.5%	100%
Riboflavin (mg)			6.7%

Table VIII. Percentage of males having a mean intake higher than the UL

	Age 19-30 years (n=150)	Age 31-50 years (n=67)	Age 51-70 years (n=15)
Magnesium (mg)	55.3%	74.6%	73.3%
Sodium (g)	82.7%	80.6%	83.3%

Table IX. Percentage of males having a mean intake higher than the AI

	Age 19-30 years (n=150)	Age 31-50 years (n=67)	Age 51-70 years (n=15)
Potassium (g)		47.8%	

Table X. Percentage of females having a mean intake below the EAR

	Age 19-30 years (n=220)	Age 31-50 years (n=138)	Age 51-70 years (n=25)
Vitamin D (μg)	94%	97%	96%
Calcium (mg)			80%

Table XI. Percentage of females having a mean intake higher than the UL

	Age 19-30 years (n=220)	Age 31-50 years (n=138)	Age 51-70 years (n=25)
Magnesium (mg)	39.5%	58.7%	52%
Sodium (g)	87.3%	89%	68%

Table XII. Percentage of females having a mean intake lower than the AI

	Age 19-30 years (n=220)	Age 31-50 years (n=138)	Age 51-70 years (n=25)
Potassium (g)	78.6%	63.8%	80%

Our study showed that dietary intakes among adults were similar among males and females with few differences found. The study documents adequate intakes of most vitamins and minerals; there were little risks of excess intakes of certain vitamins and minerals that exceed the EAR, however, were still below the UL (vitamin A, vitamin D, vitamin E, vitamin C, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, calcium, phosphorus, potassium, copper, iron, selenium and zinc) thus posing no serious health risks. In the case of vitamins, existing research findings are similar to those found in the current study. These findings include a universal concern for vitamin D deficiency among males and females around the world including western and Mediterranean countries (Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, The Netherlands, and The UK) (Manios *et al.*, 2014; Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011), as well as regional countries including Iran (Hovsepain, *et al.*, 2011; Ziaee *et al.*, 2012), Qatar (Mahdy *et al.*, 2010), and Saudi Arabia (Hussain *et al.*, 2014). Studies on Lebanese individuals including pediatrics, adults and elderly males and females showed that vitamin D deficiency has been a chronic problem (Gannage-Yared *et al.*, 2000; Hoteit *et al.*, 2014; Salamoun *et al.*, 2005). This prevalence of vitamin D deficiency worldwide could be due to several risk factors including inadequate dietary intake regardless of the composition of the diet, lack of exposure to sunlight, usage of sun screen, covering skin with clothing (Holick, 2007) malabsorptive states, and dark skin pigmentation (Holick, 2004). Our study also showed insufficient intakes of calcium among late adult females similar to results observed in western countries where intakes of calcium below the EAR were observed in more than 20% of study subjects in most countries including Poland (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014; Roman Vinas *et al.*, 2011) and the USA (U.S Department of Agriculture, 2010). Our study findings are also similar to findings reported in previous studies on potassium intake. In our study, intakes of potassium were found to be below the AI among all adult females and late adult males. Similarly, intakes of potassium below the AI were found to be highest in females especially in France, Spain, the UK and Poland (Mensink *et al.*, 2013; National Diet and Nutrition Survey, 2014). Inadequate intakes of calcium and potassium and excess intakes of sodium are all characteristics of the western diet that is being followed all over the world. Over the years, due to globalization there has been a noticeable shift from the traditional Mediterranean diet to the western diet (da Silva *et al.*, 2009) which is rich in red meats and other fatty foods, loaded with cholesterol, salt and sugar and is poor in fruits and vegetables and whole grains. This increase in the fast food pattern has been taking place among several Mediterranean countries including Lebanon (Yahia *et al.,* 2008). Food intakes of Lebanese adults have shown to be significantly different from the recommendations of the Mediterranean diet, with scores showing low adherence to this diet (Farhat *et al.*, 2016). The Mediterranean diet is characterized by the intake of high amounts of fruits, vegetables, cereals, legumes, nuts and seeds; moderate to low intake of milk, dairy products, fish and alcohol, and low intakes of red meats, while stressing on olive oil as the main source of fat (Gallus *et al.*, 2004; Noah and Truswell, 2001). A poor intake of fruits and vegetables and excess intakes of processed foods which contain fair quantities of salt explain why individuals around the world have inadequate intakes of potassium. Salt content of processed foods and fast foods consumed in a western diet can be more than 100 times higher in salt compared to similar homemade meals (Brown *et al.*, 2009).

This study is one of the very few in Lebanon to show intakes of numerous micronutrients including several vitamins that are fat-soluble and water-soluble and different micro or macro-minerals. However, the study has the following limitations: the use of a nonvalidated food frequency questionnaire in Lebanon and the small sample size of the late adulthood group as compared to the early and mid- adulthood groups.

CONCLUSION

In conclusion, diets of Lebanese individuals need improvement to prevent diet related diseases, it is clear that inadequate intakes of certain vitamins and minerals are unrecognized, and prevalent with significant health implications. More research is required to investigate dietary intakes of other populations groups including children, pregnant women and elderly. It is of crucial importance to ensure adequate nutrition; thus developing public health policies and regulatory decisions relating to the fortification of essential foods with vitamins and minerals of concern since no policy is available for food fortification such as fortifying flour and sugar especially after they are bleached which makes them lose some of their nutritional values. In addition, supplementation of individuals at risk of developing deficiencies or with deficiencies to ensure adequate consumption of vitamins and minerals should also be regarded. Awareness campaigns to increase awareness related to dietary sources of micronutrients and the potentially serious health implications associated with their deficiencies and excesses should also be designed and implemented as well.

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