Ann Ist Super Sanità 2016 | Vol. 52, No. 2: 158-166
DOI: 10.4415/ANN_16_02_06

MONOGRAPHIC SECTION

Gender-related differences in lifestyle may affect health status

Rosaria Varì[1], Beatrice Scazzocchio[1], Antonio D'Amore[1], Claudio Giovannini[1], Sandra Gessani[2] and Roberta Masella[1]

[1]*Dipartimento di Sanità Pubblica Veterinaria e Sicurezza Alimentare, Istituto Superiore di Sanità, Rome, Italy*
[2]*Dipartimento di Ematologia, Oncologia e Medicina Molecolare, Istituto Superiore di Sanità, Rome, Italy*

Abstract
Consistent epidemiological and clinical evidence strongly indicates that chronic non-communicable diseases are largely associated with four lifestyle risk factors: inadequate diet, physical inactivity, tobacco use, and excessive alcohol use. Notably, obesity, a worldwide-growing pathological condition determined by the combination between inadequate diet and insufficient physical activity, is now considered a main risk factor for most chronic diseases. Dietary habits and physical activity are strongly influenced by gender attitudes and behaviors that promote different patterns of healthy or unhealthy lifestyles among women and men. Furthermore, different roles and unequal relations between genders strongly interact with differences in social and economic aspects as well as cultural and societal environment. Because of the complex network of factors involved in determining the risk for chronic diseases, it has been promoting a systemic approach that, by integrating sex and gender analysis, explores how sex-specific biological factors and gender-related social factors can interact to influence the health status.

Key words
- dietary habits
- lifestyle
- chronic diseases
- gender
- obesity

INTRODUCTION

Non-communicable diseases (NCDs), *i.e.* chronic diseases, which include cardiovascular diseases (CVD), type 2 diabetes (T2D), cancers, and chronic respiratory diseases, represent a main sanitary and social emergency. It has been estimated that thirty eight million people die each year from these pathologies. In addition, about half of the deaths occurs between the ages 30 and 70, and mainly in the developing countries [1]. Furthermore, NCDs are the second greatest risk to global economic growth, reflecting their large economic burden [2]. These data are of great concern and represent the biggest challenge for governments since these deaths could be largely preventable by measures able to reduce risk factors. Consistent epidemiological and clinical evidence strongly indicates, in fact, that NCDs are largely associated with four modifiable lifestyle risk factors: poor diet, physical inactivity, tobacco use, and excessive alcohol use. For these reasons, in order to emphasize the importance of individual behaviors in NCD development, prevention, and treatment, chronic diseases are reported as "lifestyle-related" diseases. There is incontrovertible evidence that a bad-balanced lifestyle is associated with hypertension, increased blood sugar and cholesterol levels, and other risk factors that are precursors of chronic diseases [3, 4]. Notably, obesity, a worldwide-growing pathological condition determined by the combination between inadequate diet and insufficient physical activity, is a common denominator for most of NCDs, and an overwhelming consensus exists that it is a main player in the onset of chronic diseases, including some types of cancer [5]. In this regard, accumulating evidence points to a relationship between the low-grade systemic inflammation characterizing obesity and chronic diseases. Excess macronutrients intake and/or lipid overload associated with adiposity are thought to contribute to inflammation and aberrant signaling in adipocytes and immune cells [6]. In particular, individual nutrient intake can influence chronic inflammation [7-9]. However, the risk of developing NCDs is also heavily influenced by environmental conditions that shape individual choices. Actually, as every behavior, the lifestyle is acquired by a progressive process which starts early in the life and is largely conditioned by familiar, economic, educational, and social environment. From this point of view, it appears extremely clear that gender differences must be considered as one of the main determinants of lifestyle and, thus, of population health.

Gender-driven determinants of lifestyle

Nowadays, it is accepted that "Gender" indicates those characteristics of women and men, which are socially determined depending on psychosocial and cul-

Address for correspondence: Roberta Masella, Dipartimento di Sanità Pubblica Veterinaria e Sicurezza Alimentare, Istituto Superiore di Sanità, Viale Regina Elena 299, 00161 Rome, Italy. E-mail: roberta.masella@iss.it.

tural factors; on the contrary, "Sex" refers to those aspects that are biologically determined. We born female or male but become girls and boys, and then women and men, after learning and adopting different behaviors, strongly influenced by the social context, that ultimately lead to gender identity and gender roles (*Figure 1*). Noteworthy, differently from sex, gender behaviors are defined by sociocultural expectation, and what may be considered neutral in one culture, *e.g.* driving a car, may be considered a masculine behavior in another one [10]. In addition, gender behavior is not a dichotomous variable but it is rather defined by behavioral, psychological and cultural factors that are expressed on a continuum; this means that among two extreme behaviors, one classified clearly as masculine and another clearly defined as feminine a range of intermediate possibilities exists that are distinct but overlapping at the same time [11]. However, it is undeniable that the analysis of high-risk behaviors indicates that gender attitudes and behaviors promote different patterns of healthy or unhealthy lifestyles among women and men [12, 13]. Furthermore, different roles and unequal relations between genders strongly interact with differences in social and economic aspects such as opportunities and resources available, the possibility to make decisions, and fully exercise human rights. Taking into account this complex scenario allows us to understand the reasons why different and sometimes inequitable exposure to health risk, including bad lifestyle, occur in the population impacting on health outcomes. Consequently, it is not surprising that NCDs are reported to be the biggest threat to women's health globally, linked to 65% of female deaths worldwide [14]. In particular, CVD has been reported to be the leading cause of death in women, responsible for 33.2% of female deaths, ahead of infectious and parasitic diseases (13.9%) and cancers (13.0%) [15]. On the other hand, it has been clearly demonstrated that low socioeconomic status, strongly linked to the risk of NCDs, has a stronger effect on women than on men [16]. Finally, among women, NCDs are a more significant cause of death in low- and medium-income countries during childbearing years with respect to female in high-income countries demonstrating again the strict relationship between social and economic determinants of diseases [17]. Since 2002 World Health Organization (WHO) has been promoting an integrated approach aimed at defining every factors involved in determining the risk for NCDs [18]. In particular, by integrating sex and gender analysis into a life-course approach, it can be possible to explore how sex-specific biological factors and gender-related social factors can interact to influence health status. In this regard, a recent published evidence demonstrates that one of the common Y haplotype in Europe provides a roughly 50% higher risk of coronary artery disease regardless of the traditional CVD risk factors [19]. Another study reports that the risk of death from CVD was lower in men with a high feminine behavioral score with respect to men with a high masculine behavioral score [20]. On the other hand, recent nutrigenomic studies suggest that females and males respond differently to specific diets at the genetic, molecular, and cellular levels [21-23] (*Figure 2*). Therefore, in an era when we are moving away from generic dietary advice toward a more personalized approach to nutritional advice [24], there is a great need to establish the individual responses to treatment.

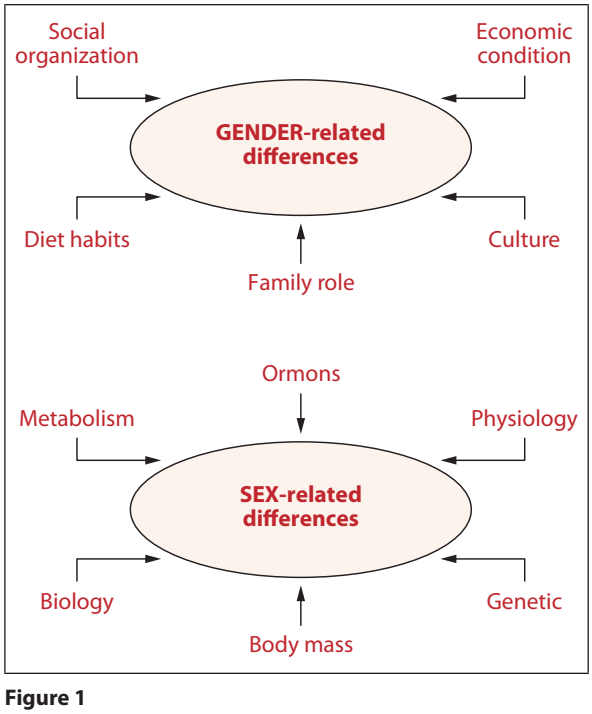

Figure 1
Environmental and biological factors that influence gender- and sex-related differences, respectively.

GENDER DIFFERENCE IN OVERWEIGHT OR OBESITY RATES

Obesity is one of the major public health concerns with prevalence rates dramatically rising worldwide suggesting that, if the recent trends continue, up to 58% of the world adult population will be overweight or obese by 2030 [25]. Obesity is a risk factor for many health conditions, such as metabolic syndrome, hypertension, dyslipidaemia, atherosclerosis, CVD, T2D, metabolic syndrome, and cancer, all of which show as common denominator an inflammatory state [6, 26].

Obesity is characterized by a pathologic expansion of adipose tissue that is caused mainly by an enlargement of pre-existing fully differentiated adipocytes due to the storage of excess energy as fat [27]. Adipose tissue expansion is critical, because it leads to insulin resistance [28], a condition of impaired response to insulin action by insulin-sensitive tissues, that is a main determinant for developing obesity-related endocrine and metabolic disturbances [29-31] as well as immune dysfunction and chronic inflammation [32, 33].

Obesity is a complex issue arising from a myriad of individual and environmental factors. The imbalance between energy intake and energy expenditure, as well as the type and quality of foods consumed, are causal factors for obesity. Consequently, poor quality of the diet and unhealthy dietary practices together with insufficient physical activity may be considered as useful

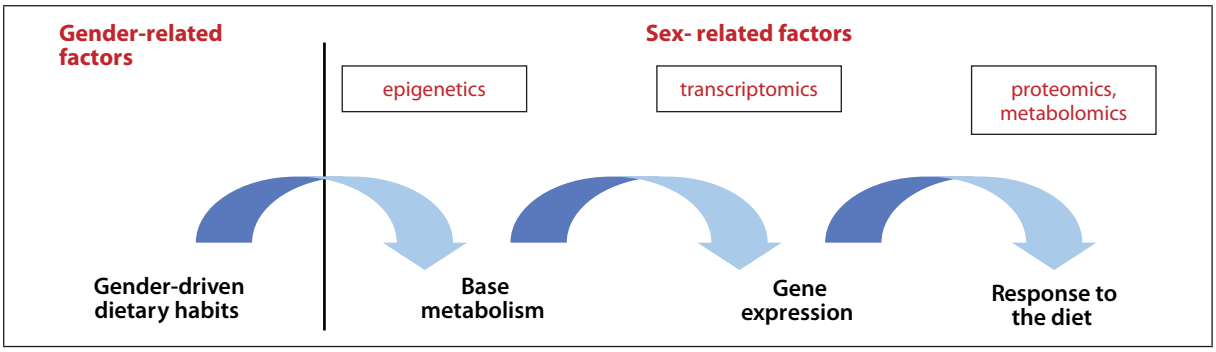

Figure 2
Interaction between gender-related food intake and sex-specific metabolism and gene expression influences individual response to the diet.

predictive tools for obesity especially in childhood [34, 35].

WHO reported that obesity incidence is increasing also in developing countries and its prevalence is higher among women than men worldwide [36]. Actually, the real cause of such gender disparity is far to be completely understood. However, some hypotheses have been formulated. Case and Menendez [37] using data collected from an informal urban settlement in South Africa, suggested two factors that were associated with obesity in women, but not in men, to explain the gender difference in obesity rates; the first one being nutritionally deprived as children; and the second one having a higher socio-economic status. As regard early life nutritional deprivation, in the patriarchal black South African society, it can be common that boys, as babies and infants, receive better care and nourishment than girls who can frequently experience hunger. This hypothesis is consistent with data collected in individuals who survived Dutch famine in 1944-45 or Great Famine in 1959-1962 in China that demonstrated increased weight and fat deposition in women, but not in men, and a high risk of obesity [38, 39].

SEX-RELATED DIFFERENCES IN LIPID STORAGE AND METABOLISM

A growing body of evidence has been collecting that clearly demonstrates relevant differences in lipid metabolism between males and females that may partially depend on sexual hormones [40]. Although the exact mechanisms regulating the different metabolic behavior are not completely understood, it is a fact that men and women, with normal BMI, are shaped differently with men showing an upper body distribution of fat (visceral fat), while women mainly a lower body distribution (subcutaneous fat). This difference in fat depot distribution is of particular interest from a clinical point of view since obesity-linked metabolic diseases such as T2D, metabolic syndrome, CVD, and cancer as well, associate mainly with the "android" distribution of fat [41, 42]. In men, the amount of visceral fat constitutes a greater proportion of the total fat mass with respect to women, especially at elevated BMIs. Women tolerate higher levels of body fat thanks to a lower amount of abdominal fat. However, they are at greater risk of obesity due to their increased propensity to gain fat. In fact, the global prevalence of obesity is higher in women than in men in all continents [25]. Therefore, over the last decades, the prevalence of abdominal obesity as well as that of the associated metabolic syndrome have increased more in women than in men [43-45].

Furthermore, sex differences in response to specific dietary intervention have been reported, in particular relating to fish oil supplementation. Enrichment of diet with n-3 polyunsaturated fatty acids (PUFA) results in higher increase of plasma n-3 PUFA in women than in men. Most likely it depends on different metabolic capacity to synthesize eicosapentaenoic acid EPA and docosahexaenoic acid (DHA) from the essential n-3 PUFA, that is linolenic acid, in premenopausal women with respect to men [46, 47] as well as on differences to metabolize and distribute differently DHA in plasma lipids [48]. However, it has been demonstrated also that the effect of PUFA supplementation on triglyceride plasma level reduction is greater in men than in women [48] demonstrating that the degree of differential responsiveness of plasma lipids and apolipoproteins to fish-oil intervention is influenced by sex.

GENDER INFLUENCES ON DIETARY HABITS AND LIFESTYLE

Gender differences have been reported for dietary intakes and eating behaviors [49]. It is matter of great concern that unhealthy behaviors such as not to consume the daily recommended five or more servings of fruit and vegetables, to skip meals, to consume frequently fast foods, and not to practice moderate-intense physical activity at least five times weekly, have been found to be common among young adults [50-53]. Previous studies have reported that women have a higher fruit and vegetables consumption and tend to have greater interest in healthy diets and a desire to eat food lower in energy than men [54, 55]. Motivation to adopt healthy eating is also recognized as an important factor in the regulation of dietary intakes and eating behaviors [56]. A recent study carried out among college students in US evidenced a significant gender difference in weight status, being the percent-

age of overweight/obese males more than double with respect to females [57]. This finding might be at least in part explained by the fact that, in general, females are more worried about their body weight and aspect than males especially in a socio-cultural environment, such as US colleges, that promotes thinness as a criterion for beauty [58]. It has been pointed out that females adopt healthier eating habits, such as having breakfast and consuming more fruit and vegetables than males [59]. On average, males consumed sugar-sweetened beverages, wine, beer, foods with high protein content more often than females [57]. Notably, several studies have reported that students, regardless the gender, generally, show a sufficient knowledge about what "healthy diet" means, but girls appeared more prone to make positive changes in nutrition and physical activity levels in order to ameliorate their own lifestyle [57, 60, 61]. Similar results have been found in a Canadian cohort that showed a healthier dietary profile adopted by women than men, especially regarding lower energy dense food intake. The study also indicates that women showed a higher awareness about eating-related issues and a higher level of motivation to adopt a better quality diet than men [62]. Interestingly, gender differences in the frequency of snacking and in the contribution of snacks to dietary intakes have been reported [63, 64]. In particular, it has been shown that snacking frequency is inversely associated with adiposity in normal-weight men and women. On the contrary, a positive association has been observed in overweight and obese women. These findings may depend on differences in the snack choice [65]. In the same vein are the results reported by the US national program National Health and Nutrition Examination Survey (NHANES) carried out in representative population of adults by gender and ethnicity. These data have shown that during the 80s and 90s women ate about 200 calories more than 30 years before especially deriving from carbohydrates (*Table 1*).

Table 1
Gender differences in dietary habits and lifestyle

Reference	Subjects description	Study	Outcomes
[56]	162 adults	Questionnaire/recall on family health history, social network and motivation to change behavior	↑ Fruits and vegetables intake ↑ physical activity in presence of one network member encouraging healthy lifestyle
[62]	♀ 59 ♂ 64 with cardiovascular risk	FFQ on dietary intake and eating behaviours	♀ healthier dietary profile and motivational variables than ♂
[60]	♀ 160 ♂ 168 University students	Questionnaire on healthy lifestyle	♀ healthier nutritional habits than ♂ and more interested in changing lifestyle
[59]	♀ 959 ♂ 761 with or not Diabetes or Hypertension	Semi-quantitative food consumption questionnaire and self-reported Diabetes and/or Hypertension status	♀ with Diabetes showed better dietary practices than ♂
[50]	♀ 2823 ♂ 1742 College students	Self-administered questionnaire on physical activity, food choice and weight management goals and practices	35% were overweight or obese; 46% were trying to lose weight (54% ♀ and 41% ♂ exercise and diet for weight control)
[51]	♀ 185 students from introductory nutrition course	Questionnaire on dietary and physical activity habits and weight perceptions	80% use dieting to lose weight 83% physical activity to control weight
[55]	14250 Norway people	Questionnaire on opinions about food and health, dietary habits and food frequency consumption	♀ follow dietary recommendations: ↑ vegetables and ↓ meat consumption than ♂
[65]	10092 people	Self-administered FFQ targeting on snacking behaviour and measures of adiposity	Snaking frequency was positively associated with higher or lower adiposity
[64]	♀ 3234 ♂ 2938	FQ targeting on snack frequency for week	♀ choose fruits like snack and ♂ prefer unhealthy food
[49]	♀ 316 ♂ 172 University students	Cross-sectional FFQ	♂ consumed more fat and fruits and vegetables than ♀
[52]	♀ 299 ♂ 49 students	Self-reported anthropometry measurements and eating attitude test	♀ healthier dieting behaviours than ♂
[57]	♀172 ♂ 65	On-line questionnaire on lifestyle and anthropometry measurements assessment	♂ higher score of mean visceral fat and waist circumference than ♀. ♀ had more healthful eating habits than ♂
[63]	♀ 2368 ♂ 1891 obese ♀ 587 ♂ 505 normal-weight	Questionnaire on lifestyle targeting on snacking frequency	Obese group consumed snack more frequently compared to the reference group and ♀ more frequently than ♂

♀: female; ♂: male; ↑: increase; ↓: decrease: FFQ: food frequency questionnaire.

GENDER-BASED INFLUENCE ON THE ASSOCIATION BETWEEN OBESITY AND DEPRESSION

The role of stress in promoting eating and obesity has been relatively well characterized. It is particularly interesting the concept generally accepted that obesity and depression are positively related in women but not in men that show no association or even an inverse association [66, 67]. However, when more precise measures of distress are used, the association tends to loose consistency [68-70]. Notably, a study carried out in US, that examined potential variation in such relationship across different racial/ethnic groups, suggested that obesity and depression are not universally positively associated, depending rather, on the social context as well as on the racial/ethnic group [71, 72]. The lack of association or the inverse association between obesity and depression observed in some US cohorts of men [70], was also reported in Asian populations [73, 74]. Trying to explain these discrepancies, it is to mention that evidence has been provided for obesogenic foods such as high-carbohydrate food and palatable calorie-dense, nutrient-poor food, often defined as " comfort food", resulting in biochemical changes that improve mood [75, 76]. On the other hand, since obese individuals are negatively considered in US society [25], it could be hypothesized that, although obesogenic foods may have some positive effects on mood, the stigma associated with obesity reduces these positive effects and results in an increased risk of depression, especially in women that are generally hurt by such weight-related discrimination [77].

EATING DISORDERS

The eating disorders, including anorexia nervosa, bulimia nervosa, binge eating disorder, and other atypical disorders, constitute a group of disorders involving disturbed body image coupled with eating and/or weight loss behaviors that cause severe distress and impairment to quality of life [78]. A strengthened and well established association between eating disorder prevalence and the female sex, as well as younger age cohort and a history of abuse, exists [79, 80]. The only exception being the Bing eating disorder, which does not appear as clearly associated with younger women, but on the contrary it is more common in older people and equally distributed among women and men [81]. The causal factors underpinning eating disorders have been studied for a long time; it appears that a complex network of possible players exists, which is able to modulate biological and psychological factors. Some aspects have been clarified by understanding about the central control of appetite; however, cultural, social, and interpersonal elements can trigger the onset, while changes in neural networks can sustain the illness [82]. For instance, many women living in Western countries may feel pressured to measure up to a certain social and cultural ideal of beauty, which can lead to poor body image. Women are constantly bombed with images presenting an ideal of body shape and size that is so difficult to achieve and maintain. Actually, youth and thinness are increasingly promoted as essential criterions of beauty, which are valid for men as well.

PHYSICAL ACTIVITY, APPETITE CONTROL AND WEIGHT LOSS PROGRAMS

Exercise is an important part of a healthy lifestyle. Indeed, diet and exercise are two lifestyle behaviors that can influence appetite and energy intake as well as diet and exercise [83, 84]; thus, ultimately altering energy balance [85]. However, the regulation of appetite and energy intake are also influenced by numerous hormonal and neural signals [86]. Actually, as for other physiological processes, the sex-mediated influences on appetite regulation and energy intake are strictly connected with those induced by gender. The type and amount of food consumed, in fact, may vary depending on one's perception of body size, concerns about own weight or, simply, health consciousness. From this point of view, women, especially those highly active, such as female athletes and exercise-trained women, may select foods lower in energy density such as whole grains, fruits and vegetables, and low fat protein sources. This is undoubtedly a correct dietary approach in general, but it may not provide adequate energy to cover activities of daily living, reproduction, and exercise energy expenditure [87]. Anyway, physical activity has been considered as an efficacious tool in body weight management and a lifestyle strategy to combat the increasing prevalence of overweight and obesity especially because it is able to increase energy expenditure [88]. Actually, although the weight loss resulting from physical activity alone appears to be modest, the addition of physical activity to a dietary intervention results in a significant improvement of the weight loss obtained with a dietary intervention alone [89, 90]. In order to define effective interventions aimed at contrasting the obesity burden by weight loss programs, several studies have been carried out both in men and women. Relevant information has been provided by the Diabetes Prevention Program [91]. The identical lifestyle intervention based on dietary and exercise strategies was carried out in more than 3000 subjects of both sexes, demonstrating that men lost more weight than women did. Indeed, this is a result common to many studies that men provide a better performance in losing weight with respect to women for any given level of effort or intensity of exercise most likely because of the fact that men generate a greater net energy expenditure. However, by analyzing data from the Midwest Exercise Trial and the Midwest Exercise Trial-II, researchers concluded that there is virtually no difference when both genders are exercising at the same absolute energy expenditure [92]. That said, it may be more challenging for women to achieve the same target exercise expenditure as men, given that they have a lower weight and lower total daily energy expenditure [93]. In this regard, a systematic review [94] reported that out of 49 high-quality studies, 11 compared directly male vs female sex differences in weight change, and 10 out of those showed that men lost more weight although women also had significant weight loss. However, another review showed that out of the 32 studies examined 50% reported higher absolute weight loss in men but the other 50% no gender differences; thus further investigation are required in

order to define if gender differences in weight loss really exist [95]. Another aspect that has attracted interest is studying the existence of gender differences in weight loss maintenance. In this regard, the same review reported that out of 12 studies that examined weight loss maintenance, 8 showed no gender difference, 3 reported men maintained their weight better, and 2 reported that women did better [95]. In a recent paper, data from NHANES were analyzed to examine if gender differences exist regarding the weight-related attitudes and behaviors in overweight/obese men and women [96]. Men were more likely to lose and maintain 4.5 kg over 1 year; in addition, they exercised more and ate less fat but they had less accurate weight perception, weight dissatisfaction and lesser attempts at weight loss than women. Women joined structured weight loss program, took prescription diet pills, and attempted special diets. These findings suggest that a need exists for gender specific intervention to improve weight perception in overweight and obese men and to help women in maintaining weight loss.

CONCLUSIONS

Gender has been recognized as an important factor that influences lifestyle habits and, consequently, the onset and course of chronic diseases. However, gender-driven differences are strictly connected with the sex-driven ones as each of them greatly impacts on dietary habits as well as on the individual response to dietary intake. Consequently, an integrated approach that puts together all the existing variables is mandatory in order to define the exact role played by each of them and to design specific intervention aimed at improving individual lifestyle and health status.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

Submitted on invitation.
Accepted on 16 March 2016.

REFERENCES

1. World Health Organization. *Noncommunicable diseases country profiles 2014*. Geneva: WHO; 2014.
2. World Economic Forum. *Global Risks 2010. A global risk network report*. Geneva: WEF; 2010.
3. Tzotzas T, Evangelou P, Kiortsis DN. Obesity, weight loss and conditional cardiovascular risk factors. *Obesity Rev* 2011;12(5): e282-9. DOI: 10.1111/j.1467-789X.2010.00807
4. Janiszewski PM, Ross R. The utility of physical activity in the management of global cardiometabolic risk. *Obesity* 2009;17(Suppl 3): S3-S14. DOI: 10.1038/oby.2009.382
5. Latino-Martel P, Cottet V, Druesne-Pecollo N, Pierre FH, Touillaud M, Touvier M, *et al*. Alcoholic beverages, obesity, physical activity and other nutritional factors, and cancer risk. A review of the evidence. *Crit Rev Oncol Hematol* 2016;99:308-23. DOI: 10.1016/j.critrevonc.2016.01.002
6. Iyer A, Fairlie DP, Prins JB, Hammock BD, Brown L. Inflammatory lipid mediators in adipocyte function and obesity. *Nat Rev Endocrinol* 2010;6:71-82.
7. Ruiz-Núñez B, Pruimboom L, Dijck-Brouwer DA, Muskiet FA. Lifestyle and nutritional imbalances associated with Western diseases: causes and consequences of chronic systemic low-grade inflammation in an evolutionary context. *J Nutr Biochem*. 2013;24(7):1183-201. DOI: 10.1016/j.jnutbio.2013.02.009
8. Myles IA Fast food fever: reviewing the impacts of the Western diet on immunity. *Nutr J* 2014;13:61. DOI: 10.1186/1475-2891-13-61
9. Thorburn AN, Macia L, Mackay CR. Diet, metabolites, and "western-lifestyle" inflammatory diseases. *Immunity* 2014;40(6):833-42. DOI: 10.1016/j.immuni.2014.05.014
10. Mahalik JR, Locke BD, Ludlow LH, Diemer MA, Scott RP, Gottfried M, Freitas G. Development of the conformity to masculine norms inventory. *Psychol Men Masc* 2003;3:25.
11. Ristvedt SL. The evolution of gender. *JAMA Psychiatry* 2014;71(1):13-14. DOI: 10.1001/jamapsychiatry.2013.3199
12. Varela-Mato V, Cancela JM, Ayan C, Martin V, Molina A. Lifestyle and health among Spanish university students: differences by gender and academic discipline. *Intern J Environ Res Publ health* 2012;9(8):2728-41. DOI: 10.3390/ijerph9082728
13. Jovicic AD. Healthy eating habits among the population of Serbia: gender and age differences. *J Health Popul Nutrition* 2015;33(1):76-84.
14. World Health Organization. *The global burden of disease: 2004 update*. Geneva: WHO; 2008.
15. McGill HC, Jr., McMahan CA, Gidding SS. Preventing heart disease in the 21st century: implications of the pathobiological determinants of atherosclerosis in youth (PDAY) study. *Circulation* 2008;117(9):1216-27. DOI: 10.1161/CIRCULATIONAHA.107.717033
16. Hayes DK, Denny CH, Keenan NL, Croft JB, Sundaram AA, Greenlund KJ. Racial/ethnic and socioeconomic differences in multiple risk factors for heart disease and stroke in women: behavioral risk factor surveillance system, 2003. *J Women's Health* 2006;15(9):1000-8. DOI: 10.1089/jwh.2006.15.1000
17. Wandera SO, Kwagala B, Ntozi J. Prevalence and risk factors for self-reported non-communicable diseases among older Ugandans: a cross-sectional study. *Global Health Action* 2015;8:27923. DOI: 10.3402/gha.v8.27923
18. World Health Organization. *WHO gender policy. Integrating gender perspectives in the work of WHO*. Geneva: WHO; 2002.
19. Charchar FJ, Bloomer LD, Barnes TA, Cowley MJ, Nelson CP, Wang Y *et al*. Inheritance of coronary artery disease in men: an analysis of the role of the Y chromosome. *Lancet* 2012;379(9819):915-22. DOI: 10.1016/S0140-6736(11)61453-0
20. Hunt K, Lewars H, Emslie C, Batty GD. Decreased risk of death from coronary heart disease amongst men with higher 'femininity' scores: a general population cohort study. *Intern J Epidemiol* 2007;36(3):612-20. DOI: 10.1093/ije/dym022
21. Phillips CM, Goumidi L, Bertrais S, Field MR, McManus R, Hercberg S, *et al*. Dietary saturated fat, gender and genetic variation at the TCF7L2 locus predict the de-

velopment of metabolic syndrome. *J Nutr Biochem* 2012; 23(3):239-44. DOI: 10.1016/j.jnutbio.2010.11.020

22. Phillips CM, Goumidi L, Bertrais S, Field MR, McManus R, Hercberg S, *et al.* Gene-nutrient interactions and gender may modulate the association between ApoA1 and ApoB gene polymorphisms and metabolic syndrome risk. *Atherosclerosis* 2011; 214(2):408-14. DOI: 10.1016/j.atherosclerosis.2010.10.029
23. Ordovas JM, Corella D, Cupples LA, Demissie S, Kelleher A, Coltell O *et al.* Polyunsaturated fatty acids modulate the effects of the APOA1 G-A polymorphism on HDL-cholesterol concentrations in a sex-specific manner: the Framingham Study. *Am J Clinical Nutr* 2002;75(1):38-46.
24. Joost HG, Gibney MJ, Cashman KD, Gorman U, Hesketh JE, Mueller M *et al.* Personalised nutrition: status and perspectives. *Br J Nutrition* 2007;98(1):26-31. DOI: 10.1017/S0007114507685195
25. Kelly T, Yang W, Chen CS, Reynolds K, He J. Global burden of obesity in 2005 and projections to 2030. *Intern J Obesity* 2008;32(9):1431-7. DOI: 10.1038/ijo.2008.102
26. Eckel RH, Krauss RM. American Heart Association call to action: obesity as a major risk factor for coronary heart disease. AHA Nutrition Committee. *Circulation* 1998;97(21): 2099-100.
27. Spalding KL, Arner E, Westermark PO, Bernard S, Buchholz BA, Bergmann O *et al.* Dynamics of fat cell turnover in humans. *Nature* 2008;453(7196):783-7. DOI: 10.1038/nature06902
28. Lundgren M, Svensson M, Lindmark S, Renstrom F, Ruge T, Eriksson JW. Fat cell enlargement is an independent marker of insulin resistance and "hyperleptinaemia". *Diabetologia* 2007;50(3):625-33. DOI: 10.1007/s00125-006-0572-1
29. Khandekar MJ, Cohen P, Spiegelman BM. Molecular mechanisms of cancer development in obesity. *Nature reviews. Cancer* 2011;11(12):886-95. DOI: 10.1038/nrc3174
30. Klop B, Elte JW, Cabezas MC. Dyslipidemia in obesity: mechanisms and potential targets. *Nutrients* 2013;5(4):1218-40. DOI: 10.3390/nu5041218
31. Rask-Madsen C, Kahn CR. Tissue-specific insulin signaling, metabolic syndrome, and cardiovascular disease. *Arterioscl Thromb Vascular Biol* 2012;32(9):2052-9. DOI: 10.1161/ATVBAHA.111.241919
32. Hotamisligil GS. Inflammation and metabolic disorders. *Nature* 2006;444(7121):860-7. DOI: 10.1038/nature05485
33. Vandanmagsar B, Youm YH, Ravussin A, Galgani JE, Stadler K, Mynatt RL, *et al.* The NLRP3 inflammasome instigates obesity-induced inflammation and insulin resistance. *Nat Med* 2011;17(2):179-88. DOI: 10.1038/nm.2279
34. Perry CP, Keane E, Layte R, Fitzgerald AP, Perry IJ, Harrington JM. The use of a dietary quality score as a predictor of childhood overweight and obesity. *BMC Publ Health* 2015;15:581. DOI: 10.1186/s12889-015-1907-y
35. Reilly JJ, Ness AR, Sherriff A. Epidemiological and physiological approaches to understanding the etiology of pediatric obesity: finding the needle in the haystack. *Pediat Res* 2007;61(6):646-52. DOI: 10.1203/pdr.0b013e3180536667
36. World Health Organization. *Obesity and Overweight. WHO Global InfoBase*. Available from: www.who.int/topics/obesity/en/.
37. Case A, Menendez A. Sex differences in obesity rates in poor countries: evidence from South Africa. *Econ Hum Biol* 2009;7(3):271-82. DOI: 10.1016/j.ehb.2009.07.002
38. Stein AD, Kahn HS, Rundle A, Zybert PA, van der Pal-de Bruin K, Lumey LH. Anthropometric measures in middle age after exposure to famine during gestation: evidence from the Dutch famine. *Am J Clin Nutr* 2007;85(3):869-76.
39. Zhehui L, Ren Mu, Zhang, X. Famine and overweight in China. *Rev Agricultural Econ* 2006;28(3):296-304.
40. Santosa S, Jensen MD. The sexual dimorphism of lipid kinetics in humans. *Frontiers Endocrinol* 2015;6:103. DOI: 10.3389/fendo.2015.00103
41. Jensen MD. Role of body fat distribution and the metabolic complications of obesity. *J Clin Endocrinol Metabol* 2008;93(11 Suppl 1):S57-63. DOI: 10.1210/jc.2008-1585
42. Britton KA, Massaro JM, Murabito JM, Kreger BE, Hoffmann U, Fox CS. Body fat distribution, incident cardiovascular disease, cancer, and all-cause mortality. *J Am College Cardiol* 2013;62(10):921-5. DOI: 10.1016/j.jacc.2013.06.027
43. Ford ES, Giles WH, Mokdad AH. Increasing prevalence of the metabolic syndrome among U.S. adults. *Diab Care* 2004;27(10):2444-9.
44. Al-Lawati JA, Mohammed AJ, Al-Hinai HQ, Jousilahti P. Prevalence of the metabolic syndrome among Omani adults. *Diab Care* 2003;26(6):1781-5.
45. Gu D, Reynolds K, Wu X, Chen J, Duan X, Reynolds RF, *et al.* Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet* 2005;365(9468):1398-405. DOI: 10.1016/S0140-6736(05)66375-1
46. Burdge GC. Metabolism of alpha-linolenic acid in humans. *Prostagland Leukotr Essential Fatty Scids* 2006;75(3):161-8. DOI: 10.1016/j.plefa.2006.05.013
47. Burdge GC, Calder PC. Conversion of alpha-linolenic acid to longer-chain polyunsaturated fatty acids in human adults. *Reproduct Nutrition Ddevelop* 2005;45(5):581-97. DOI: 10.1051/rnd:2005047
48. Caslake MJ, Miles EA, Kofler BM, Lietz G, Curtis P, Armah CK *et al.* Effect of sex and genotype on cardiovascular biomarker response to fish oils: the FINGEN Study. *Am J Clin Nutr* 2008;88(3):618-29.
49. Li KK, Concepcion RY, Lee H, Cardinal BJ, Ebbeck V, Woekel, E *et al.* An examination of sex differences in relation to the eating habits and nutrient intakes of university students. *J Nutr Educ Behav* 2012;44(3):246-50. DOI: 10.1016/j.jneb.2010.10.002
50. Lowry R, Galuska DA, Fulton JE, Wechsler H, Kann L, Collins JL. Physical activity, food choice, and weight management goals and practices among US college students. *Am J Prev Med* 2000;18(1):18-27.
51. Malinauskas BM, Raedeke TD, Aeby VG, Smith JL, Dallas MB. Dieting practices, weight perceptions, and body composition: a comparison of normal weight, overweight, and obese college females. *Nutr J* 2006;5:11. DOI: 10.1186/1475-2891-5-11
52. Sira N, Pawlak R. Prevalence of overweight and obesity, and dieting attitudes among Caucasian and African American college students in Eastern North Carolina. A cross-sectional survey. *Nutr Res Practice* 2010;4(1):36-42. DOI: 10.4162/nrp.2010.4.1.36
53. McTigue KM, Garrett JM, Popkin BM. The natural history of the development of obesity in a cohort of young U.S. adults between 1981 and 1998. *Ann Internal Med* 2002;136(12):857-64.
54. Rolls BJ, Fedoroff IC, Guthrie JF. Gender differences in eating behavior and body weight regulation. *Health Psychology* 1991;10(2):133-42.
55. Fagerli RA, Wandel M. Gender differences in opinions and practices with regard to a "healthy diet". *Appetite*

1999;32(2):171-90. DOI: 10.1006/appe.1998.0188
56. Ashida S, Wilkinson AV, Koehly LM. Social influence and motivation to change health behaviors among Mexican-origin adults: implications for diet and physical activity. *Am J Health Promotion* 2012;26(3):176-9. DOI: 10.4278/ajhp.100107-QUAN-2
57. Yahia N, Wang D, Rapley M, Dey R. Assessment of weight status, dietary habits and beliefs, physical activity, and nutritional knowledge among university students. *Perspect Publ Health* 2015. DOI: 10.1177/1757913915609945
58. Ferguson CJ, Winegard B, Winegard BM. Who is the fairest one of all? How evolution guides peer and media influences on female body dissatisfaction. *Rev Gen Psychol* 2011;15(1):11-28.
59. Ozcariz SG, Bernardo Cde O, Cembranel F, Peres MA, Gonzalez-Chica DA. Dietary practices among individuals with diabetes and hypertension are similar to those of healthy people: a population-based study. *BMC Publ Health* 2015;15:479. DOI: 10.1186/s12889-015-1801-7
60. von Bothmer MI, Fridlund B. Gender differences in health habits and in motivation for a healthy lifestyle among Swedish university students. *Nurs Health Sci* 2005;7(2):107-18. DOI: 10.1111/j.1442-2018.2005.00227.x
61. Livingston IL, Saafir BD, Manuel RC. Health knowledge among historically black college and university students: An exploratory study. *College Student J* 2012;46(3):581-8.
62. Leblanc V, Begin C, Corneau L, Dodin S, Lemieux S. Gender differences in dietary intakes: what is the contribution of motivational variables? *J Hum Nutrition Dietetics* 2015;28(1):37-46. DOI: 10.1111/jhn.12213
63. Berteus Forslund H, Torgerson JS, Sjostrom L, Lindroos AK. Snacking frequency in relation to energy intake and food choices in obese men and women compared to a reference population. *Int J Obesity* 2005;29(6):711-9. DOI: 10.1038/sj.ijo.0802950
64. Hartmann C, Siegrist M, van der Horst K. Snack frequency: associations with healthy and unhealthy food choices. *Public Health Nutr* 2013;16(8):1487-96. DOI: 10.1017/S1368980012003771
65. O'Connor L, Brage S, Griffin SJ, Wareham NJ, Forouhi NG. The cross-sectional association between snacking behaviour and measures of adiposity: the Fenland Study, UK. *Br J Nutrition* 2015;114(8):1286-93. DOI: 10.1017/S000711451500269X
66. de Wit L, Luppino F, van Straten A, Penninx B, Zitman F, Cuijpers P. Depression and obesity: a meta-analysis of community-based studies. *Psychiat Res* 2010;178(2):230-5. DOI: 10.1016/j.psychres.2009.04.015
67. Luppino FS, de Wit LM, Bouvy PF, Stijnen T, Cuijpers P, Penninx BW, *et al.* Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Arch Gen Psychiatry* 2010;67(3):220-9. DOI: 10.1001/archgenpsychiatry.2010.2
68. Needham BL, Epel ES, Adler NE, Kiefe C. Trajectories of change in obesity and symptoms of depression: the CARDIA study. *Am J Public Health* 2010;100(6):1040-6. DOI: 10.2105/AJPH.2009.172809
69. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *Jama* 2010;303(3):235-41. DOI: 10.1001/jama.2009.2014
70. Faith MS, Butryn M, Wadden TA, Fabricatore A, Nguyen AM, Heymsfield SB. Evidence for prospective associations among depression and obesity in population-based studies. *Obesity Rev* 2011;12(5):e438-53. DOI: 10.1111/j.1467-789X.2010.00843.x
71. Hicken MT, Lee H, Mezuk B, Kershaw KN, Rafferty J, Jackson JS. Racial and ethnic differences in the association between obesity and depression in women. *J Women's Health* 2013;22(5):445-52. DOI: 10.1089/jwh.2012.4111
72. Assari S, Caldwell CH. Gender and ethnic differences in the association between obesity and depression among black adolescents. *J Racial Ethnic Health Dispar* 2015;2(4):481-93. DOI: 10.1007/s40615-015-0096-9
73. Dong Q, Liu JJ, Zheng RZ, Dong YH, Feng XM, Li J, *et al.* Obesity and depressive symptoms in the elderly: a survey in the rural area of Chizhou, Anhui province. *Int J Geriatr Psychiatry* 2013;28(3):227-32. DOI: 10.1002/gps.3815
74. Atlantis E, Baker M. Obesity effects on depression: systematic review of epidemiological studies. *Intern J Obesity* 2008;32(6):881-91. DOI: 10.1038/ijo.2008.54
75. Dallman MF, Pecoraro NC, la Fleur SE. Chronic stress and comfort foods: self-medication and abdominal obesity. *Brain Behav Immun* 2005;19(4):275-80. DOI: 10.1016/j.bbi.2004.11.004
76. Dallman MF, Pecoraro N, Akana SF, La Fleur SE, Gomez F, Houshyar H, *et al.* Chronic stress and obesity: a new view of "comfort food". *Proceedings of the National Academy of Sciences of the United States of America* 2003;100(20):11696-701. DOI: 10.1073/pnas.1934666100
77. Tomiyama AJ, Dallman MF, Epel ES. Comfort food is comforting to those most stressed: evidence of the chronic stress response network in high stress women. *Psychoneuroendocrinology* 2011;36(10):1513-9. DOI: 10.1016/j.psyneuen.2011.04.005
78. Jenkins PE, Hoste RR, Meyer C, Blissett JM. Eating disorders and quality of life: a review of the literature. *Clin Psychol Rev* 2011;31(1):113-21. DOI: 10.1016/j.cpr.2010.08.003
79. Mitchison D, Hay PJ. The epidemiology of eating disorders: genetic, environmental, and societal factors. *Clin Epidemiol* 2014;6:89-97. DOI: 10.2147/CLEP.S40841
80. American Psychiatric Association. *Diagnostic and statistical manual of mental disorders. Fifth Edition.* Washington DC: APA-Publishing; 2015.
81. Striegel-Moore RH, Franko DL. Epidemiology of binge eating disorder. *Int J Eating Disord* 2003;34Suppl:S19-29. DOI: 10.1002/eat.10202
82. Treasure J, Claudino AM, Zucker N. Eating disorders. *Lancet* 2010;375(9714):583-93. DOI: 10.1016/S0140-6736(09)61748-7
83. Evero N, Hackett LC, Clark RD, Phelan S, Hagobian TA. Aerobic exercise reduces neuronal responses in food reward brain regions. *J Appl Physiol* 2012;112(9):1612-9. DOI: 10.1152/japplphysiol.01365.2011
84. Cornier MA, Melanson EL, Salzberg AK, Bechtell JL, Tregellas JR. The effects of exercise on the neuronal response to food cues. *Physiol Behav* 2012;105(4):1028-34. DOI: 10.1016/j.physbeh.2011.11.023
85. Schubert MM, Sabapathy S, Leveritt M, Desbrow B. Acute exercise and hormones related to appetite regulation: a meta-analysis. *Sports Med* 2014;44(3):387-403. DOI: 10.1007/s40279-013-0120-3
86. Coll AP, Farooqi IS, O'Rahilly S. The hormonal control of food intake. *Cell* 2007;129(2):251-62. DOI: 10.1016/j.cell.2007.04.001
87. Howe SM, Hand TM, Manore MM. Exercise-trained men and women: role of exercise and diet on appetite and energy intake. *Nutrients* 2014;6(11):4935-60. DOI: 10.3390/nu6114935
88. Ravussin E, Bogardus C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization *Am J Clin Nutr*1989;49:968-75.

89. Jakicic JM. The effect of physical activity on body weight. *Obesity* 2009;17 Suppl 3.
90. Greaves CJ, Sheppard KE, Abraham C, Hardeman W, Roden M, Evans PH, Schwarz P, IMAGE Study Group. Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. *BMC Public Health* 2011;11:119.
91. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM, Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002;346(6):393-403.
92. Donnelly JE, Honas JJ, Smith BK, Mayo MS, Gibson CA, Sullivan DK, Lee J, Herrmann SD, Lambourne K, Washburn RA. Aerobic exercise alone results in clinically significant weight loss for men and women: midwest exercise trial 2. *Obesity (Silver Spring)* 2013;21(3):E219-28. DOI: 10.1002/oby.20145.
93. Hagobian TA, Yamashiro M, Hinkel-Lipsker J, Streder K, Evero N, Hackney T. Effects of acute exercise on appetite hormones and ad libitum energy intake in men and women. *Appl Physiol Nutr Metab* 2013;38(1):66-72. DOI: 10.1139/apnm-2012-0104.
94. Williams RL, Wood LG, Collins CE,. Callister R. Effectiveness of weight loss interventions – is there a difference between men and women: a systematic review. *Obesity Rev* 2015;16:171-86.
95. Mora N, Rieke K, Plitcha J, Segura A, Leehey D, DeShong K, Kramer H, Durazo-Arvizu RA. 25-hydroxyvitamin D supplementation and BMI change. A meta-analysis of randomized controlled trials. *J Obes Weight Loss Ther* 2013;3(4):181.
96. Tsai SA, Lv N, Xiao L, Ma J. Gender differences in weight-related attitudes and behaviors among overweight and obese adults in the United States. *Am J Mens Health* 2015. Epub ahead of print.