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Effect of various diets on biomarkers of the metabolic syndrome.

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List of abbreviations

BMI: body mass index

BP: blood pressure

C3: complement C3

hsCRP: high sensitive C-reactive protein

DASH: dietary intake to stop hypertension

DHA: docosahexaenoic acid

HDL: high-density lipoprotein

HDL-c: HDL-cholesterol

HOMA-IR: homeostasis model assessment of insulin resistance

IL: interleukin

LDL: low-density lipoprotein

LDL-c: HDL-cholesterol

Lp-PLA2: lipoprotein-associated phospholipase A2

MDA: malondialdehyde

MetS: metabolic syndrome

NNR: Nordic nutrition recommendation

oxLDL: oxidized LDL

PAI-1: plasminogen activator inhibitor-1

PON-1: paraxonase-1

PUFA: polyunsaturated fatty acids

RBP4: retinol-binding protein 4

sICAM-1: soluble intercellular adhesion molecule-1

sVCAM-1: soluble vascular cell adhesion molecule-1

TAC: total antioxidant capacity

TBARS: thiobarbituric acid reactive substances

TC: total cholesterol

TG: triglycerides

TNF-α: tumor necrosis factor-α

VLDL: very low-density lipoprotein

Introduction

Metabolic syndrome (MetS), also called "insulin resistance syndrome" (DeFronzo et al. 1991), "deadly quartet" (Kaplan 1989), or "syndrome X" (Reaven 1988), is characterized by abdominal obesity, hypertriglyceridemia, relatively low high-density lipoprotein (HDL) cholesterol concentration, increased blood pressure, and elevated glucose level (Grundy et al. 2005).
Although the exact aetiology of MetS has not yet been completely elucidated, many cross-sectional or longitudinal studies, have shown that MetS is strongly associated with insulin resistance (Lann & LeRoith 2007), oxidative stress (Onat et al. 2006), inflammation (Festa et al. 2000), endothelial dysfunction (Tziomalos et al. 2010) and risk of cardiovascular diseases (Lakka et al. 2002).

Most research groups use a mixture of biomarkers as indicator for MetS (Mansoub et al. 2006; Srikanthan et al. 2016). Metabolic overload (high caloric intake) evokes oxidative stress, which can lead to low-grade of inflammation and result in a cardiovascular risk. Therefore, due to this sequence of actions, dividing the biomarkers of MetS into four groups (dyslipidemias, markers of oxidative stress and inflammation, and cardio-metabolic markers) seems quite logic.
Earlier we have discussed the biochemical action and clinical significance of these markers in an extensive review article (Robberecht & Hermans 2016).

There are no individual dietary components that could be considered as solely responsible for the association with MetS. The overall quality of the diet will offer protection against this lifestyle disease (Baxter et al. 2006) and, besides macronutrients and micronutrients, also phytochemicals, as well as their metabolites can affect MetS in various ways, even in an epigenetic way (Szarc vel Szic et al. 2015). Therefore we intend to review the impact of total diet in different countries and of special types of diet on the biomarkers of MetS.

Out of the tremendous amount of literature data we have tried to limit us to MetS patients only, but this is not always that straightforward, since description of studied population is not that accurate and some pathologies are overlapping.
Since the benefits of some food patterns, especially the Mediterranean diet are frequently reported and quite promising, we have studied these more in detail.
Vegetarian diets are quite well mentioned in literature, but also here there is a large spectrum in diet consistency and descriptions, going from strict vegan, over ovo-lacto up to even pesco-vegetarians.

1. Whole diet in various countries

A whole diet approach is particularly promising in reducing processes associated with MetS, since this not only involves all macro- and micronutrients, but also other biologically active components present. Major dietary patterns are significantly associated with the risk of metabolic syndrome (Amini et al. 2010).

Concerning food in relation to MetS, there has been a switch from limiting total fat to a focus on the quality of the fat, with evidence of beneficial effects replacing carbohydrate by monounsaturated fat. Dietary habits currently recommended as "healthy" are likely also protective against MetS, including low saturated and trans-fatty acids intake (rather than low total fat) and a diet rich in dietary fiber, as well as high fruit and vegetable consumption (rather than low total carbohydrate); and the inclusion of low-fat dairy foods (Feldeisen & Tucker 2007).

A systematic review and meta-analysis revealed that a low-fat diet, diet high in soy protein, fiber or phytosterols, whole grain foods, and ω-3 fatty acid supplementation, improved lipid profiles (Huang et al. 2011)
Dietary patterns high in sugars, saturated and trans-fatty acids, poor in natural antioxidants and fibers from fruits, vegetables, and whole grains, and poor in ω-3 fatty acids may cause an activation of the innate immune system, with most likely an excessive production of pro-inflammatory cytokines and a reduced production of anti-inflammatory cytokines (Garcia et al. 2014).

Prospective findings suggest that consumption of a Western dietary pattern with meat and fried foods promotes the incidence of MetS, whereas dairy consumption provides some protection (Lutsey et al. 2008).
However, research from various countries on the effects of dairy products on inflammation, oxidative stress and adiponectin levels has shown conflicting results (Zemel & Sun 2008; Wennersberg et al. 2009; Lee et al. 2016). Low-fat milk consumption may have a favorable effect on atherogenic markers in subjects with high blood pressure or hypertriglyceridemia (Lee et al. 2016).

Significant associations exist between dietary patterns and MetS as identified by factor analysis for female Tehrani teachers (Esmailzadeh et al. 2007). However the description of a healthy dietary pattern, a Western and a traditional dietary pattern is not well-defined, making it difficult to compare with patterns in other countries. Also the number of persons in the studied populations is quite limited.

For elderly women no associations were observed between dietary intake and the prevalence of MetS. This is possibly due to the fact that these factors have an influence in earlier phases of life or take longer to result in an effect. The recent change was not able to prevent establishment of the syndrome (Bruscato et al 2010).
Quite recently a multifunctional diet, characterized by a combination of low-glycemic-index meals, soybean and soy-protein-containing products, almonds, whole barley kernel products, plant stanols, fatty marine fish as source of long-chain ω-3 fatty acids, foods and ingredients rich in natural antioxidants and soluble dietary fiber, decreased blood lipids and improved several other aspects of the cardio-metabolic risk profile in healthy overweight and obese subjects. This effect was not dependent on weight loss (Tovar et al. 2015).

A meta-analysis of consumption of a healthy dietary pattern revealed a significant reduction in C-reactive protein levels in adults, but non-significant changes were found for all other biomarkers (Neaale et al. 2016).
A review on the effects of selected healthy nutrition models in humans on the concentration of CRP and IL-6 showed that the Mediterranean diet model was most effective in lowering these inflammatory markers. The dietary approach to stop hypertension model (DASH) and the plant nutrition model also have proven to be beneficial. The data on low-fat and low carbohydrate diets and their effect on biomarkers were inconclusive (Smidowicz & Regula 2015).
RESMENA-S (Metabolic Syndrome Reduction in Navarra-Spain) study evaluated the effect of a novel strategy involving a modified macronutrient distribution, higher meal frequency, increased fiber and ω-3 fatty acids consumption, low glycemic index and glycemic load and high total antioxidant capacity (TAC) food (Zulet et. 2011) and compared it with the American Heart Association guidelines, which is currently considered as a reference dietary pattern to reduce fat mass content and improve MetS markers (Kraus et al. 2000). The study proved that RESMENA diet was as effective for reducing MetS features. Dietary TAC was the most contributing factor involved in body weight and obesity related markers (Lopez-Legarra et al. 2013).

Table 1 summarizes some results found for various countries. Diet type, specification, risk of MetS and studied biomarkers, as far as could be traced are included.
As can be seen from this table results are not always consistent. Before definite conclusions can be drawn, accurate specifications of diet type are of paramount importance. Besides that, studied population (age, sample size, other characteristics, like BMI) and even gender (Xu et al. 2016; Mennen et al. 2000; Kang & Kim 2014) are also important. Other confounding factors in a study design could be the duration, adherence to diet and control diet.

For a Western or westernized type of diet, all depends on what is included in this term. Sometimes the notion “fast food” is used for this high fat and protein-rich diet, with low phytochemical and low fiber products. Higher consumption of these fast foods had undesirable effects on MetS after 3-years of follow-up in Iranian adults (Bahadoran et al. 2013). Here, an increase in serum triglyceride levels and triglyceride to HDL-cholesterol ratio was observed. This promoting effect contradicts the decreased risk on MetS in Japan for people consuming a “westernized breakfast” (Bian et al. 2013). Also the subjectivity of a dietary pattern technique (recall method, a posteriori), a single 24-h recall, which is not representing the usual intake, cross-sectional design or longitudinal studies, intervention and time hereof can all jeopardize definite conclusions.

For some countries (e.g. Korea) the dietary patterns in relation to MetS are quite well studied. After assessment of intake by recall methods various patterns were observed. Kim and Yo 2011 studied four dietary patterns: white rice and kimchi; meat and alcohol; high fat, sweets and coffee; and grains, vegetables, and fish. It turned out that the latter diet may be associated with lower risk of MetS.
Song and Joung 2012 selected three patterns after cluster analysis: “traditional”, “meat and alcohol” and “Korean healthy”. The traditional group was characterized by high consumption of rice and kimchi, while the ”Korean healthy” group ate a modified Korean-style diet with various foods such as

noodles, bread, eggs and milk. The “meat and alcohol” group had a higher consumption of processed meat and alcohol.
Koreans, following the traditional dietary pattern, had beneficial effects with respect to some metabolic abnormalities. However, in this group the high prevalence of low HDL-cholesterol , attributable to a high-carbohydrate diet, should be considered (Song & Joung 2012).
Choi et al. 2015 identified three dietary patterns: “traditional”, “western”, and “prudent”. The “prudent” dietary pattern consisted of high intake of fruit and fruit products, as well as nuts, dairy and a low consumption of grains. This pattern was negatively associated with the risk of MetS among Korean women.
Cho et al. 2015 studied three dietary patterns (Western, healthy and traditional) and their results suggest that the healthy pattern is associated with a reduced risk for MetS, particularly in postmenopausal women. The traditional pattern was positively associated with hypertriglyceridemia and low HDL-cholesterol in women only (Kang & Kim 2015).
For the same postmenopausal women, the risk of MetS was lower in the group of the rice with beans and rice with multi-grains group, compared to the white rice group (Ahn et al. 2013).
Woo et al. 2014 identified three distinct patterns: “traditional”, “meat” and a “snack” pattern. It was very hard to trace what was mentioned by the “snack” pattern. The traditional and the snack group were not associated with a higher prevalence of MetS. However, the meat dietary pattern was associated with a higher prevalence of MetS in Korean male adults.
Along with the economic development and globalization Korean diet has changed over a few decades, from traditional diet, mainly composed of rice and vegetables, to westernized diet, rich in meat and milk. Intake of milk and dairy products turned out to be negatively associated with MetS risk (Shin et al. 2013; Jun et al. 2012; Hong et al. 2012), as was also reported in Western countries. A fruit and dairy pattern is associated with a reduced risk of having MetS (Hong et al. 2012).
Supplementing a usual Korean diet with mixed nuts (30 g/day of walnuts, peanuts, and pine nuts for 6 weeks) had favorable effects on several lipid parameters (lower TC and non-HDL-cholesterol) in Korean women with MetS (Lee et al. 2014).

However, interpreting these results one should always keep in mind, that no single dietary variable can be considered as solely responsible for the association of a diet with the MetS. Moreover, especially cross-sectional design limits causal inference between dietary factors and metabolic abnormalities.

2. Various diet types

The characteristics of three promising diet types (Mediterranean, Nordic and DASH) are summarized in table 2.

2.1. Mediterranean diet
The traditional Mediterranean diet is low in saturated fat, high in monounsaturated fat (mainly olive oil), high in complex carbohydrates (from legumes) and high in fiber (mostly from vegetables and fruits) (Espino-Montoro et al. 1996; Calton et al. 2014). Other favorable characteristics are red wine consumption and a lower content of refined carbohydrates in the diet (Giugliano et al. 2008; Perez-Martinez et al. 2011).

Olives, or olive oil, not only contain unsaturated fatty acids, but also phenolic compounds which confer virgin olive oil additional effects. Being strong antioxidants, they are able to reduce oxidative stress (Razquin et al. 2009; Urpi-Sarda et al. 2012; Mitjavila et al. 2013; Bekkouche et al. 2014). Polyphenols inhibit copper-mediated low density lipoprotein (LDL) oxidation in a concentration dependent manner (Leenen et al. 2002).
Since elevated serum resistin concentrations in humans have also been linked to inflammatory processes and atherosclerosis (Reilly et al. 2005), the lower resistin gene expression after polyphenol consumption may be responsible for a lower grade of inflammation. Olive oil consumption however proved to have only marginal effect on serum resistin levels (Machowetz et al. 2008). However, the studied group was a healthy male population and no comparison with MetS patients was included.

There is a lot of evidence suggesting that the Mediterranean diet could serve as an anti-inflammatory diet which could help to fight diseases related to chronic inflammation (Giugliano & Esposito 2008; Daj et al. 2008; Babio et al. 2009; Richard et al. 2013; Viscogliosi et al. 2013; Ahluwalia et al. 2013) and its associated cardiovascular risk (Dai et al. 2008; Esposito et al. 2004; Serrano-Martinez et al. 2005; Esposito et al. 2013).
Lower serum concentrations of the inflammatory markers, especially those related to endothelial function are registered in patients with consumption of typical Mediterranean foods (Salas-Salvado et al. 2008). Higher consumption of low-fat dairy products, yogurt and low-fat milk was associated with a reduced risk of MetS. Quite contradictory, higher consumption of cheese was related to a higher risk of MetS (Babio et al. 2015).
Only one publication could be traced, concluding no effect of a Mediterranean diet on markers of inflammation and metabolic risk factors in patients with coronary artery disease (Michalson et al. 2006). Some comments on this study with a non-Mediterranean population have been published, regarding the diet and the absence of a control occidental type of feeding (Serrano-Martinez et al. 2007).

Meta-analysis of epidemiological studies and randomized clinical trials showed that adherence to the Mediterranean diet was associated with a reduced risk of MetS (; Giugliano et al. 2008; Babio et al. 2009; Perez-Martinez et al. 2011; Kastorini et al. 2011; Gotsis et al. 2015; Smidowicz & Regula 2015). Adherence to a Mediterranean-like diet may decrease the risk of MetS also among a non-Mediterranean population (Grosso et al. 2015).The protective role was illustrated by lower concentrations of triglycerides (Michalsen et al. 2006) and glucose (Babio et al. 2009; Kastorini et al. 2011) and a higher level of high-density lipoprotein cholesterol (Kastorini et al. 2011).

The increased consumption of ω-3 fatty acids, zinc, vitamin E, Se and decreased consumption of saturated fatty acids, improved the lipid profile of children and adolescents with obesity (Velazquez-Lopez et al. 2014). ω-3 PUFAs and virgin olive oil may have beneficial synergistic effects on lipid metabolism and oxidative stress in patients with MetS (Venturini et al. 2015).
Higher plasma levels of carotenoids, vitamin A and vitamin E, together with the endogenous antioxidants, a high level of the anti-inflammatory cytokine IL-10, a lower level of the pro-inflammatory cytokine TNF-α and a lower level of MDA would explain the lower incidence of MetS in an Italian population (Azzini et al. 2011). The diet gradually induced a significant reduction in total cholesterol, LDL-c, triglycerides, hsCRP, and blood pressure (Athyros et al. 2011).

Adherence to this low-glycemic-load diet for 12 weeks increases plasma carotenoids and decreases LDL-oxidation in women with MetS (Barona et al. 2012).
A Mediterranean diet enriched with nuts could be beneficial for MetS management, due to the modulation of inflammation and oxidation (Salas-Salvado et al. 2014). The diet plus a medical food containing phytosterols, soy protein and extracts from hops and acacia results in a less atherogenic lipoprotein profile (Barona et al. 2012; Salas-Salvado et al. 2014), lower plasma homocysteine (Jones et al. 2011) and apoB (Jones et al. 2012). Short time dietary supplementation of an oil combination (borage/echium) significantly lowered total and LDL-cholesterol (Lee et al. 2014).
A decrease in blood glucose, blood pressure and waist circumference (Garcia et al. 2016), decreased inflammation and an improvement of endothelial function was observed (Schwingskackl & Hoffman 2014), as was noticed by the response on biomarkers of inflammation (CRP), adhesion molecules (sICAM-1, sVCAM-1), cytokines (IL-1, IL-6 and -7) and molecules related to the stability of atheromatic plaque (Casas et al. 2014).
A long-term weight loss intervention with a low-fat, low-carbohydrate Mediterranean diet revealed a continued long-term improvement of hsCRP, HDL-c, adiponectin, fetuin-A, progranulin, and vaspin levels, even despite of a partial weight regain (Blüher et al. 2012).
Following a hypocaloric diet accompanying a high adherence to a Mediterranean dietary pattern resulted in reduction of pro-inflammatory markers (RBP4, leptin, CRP, C3 and TNF-α). In addition a significant improvement in some metabolic features was induced by weight loss (Hermsdorff et al. 2009).

Increases in biomarkers of foods supplied by the Mediterranean diet, i.e., oleic and α-linolenic acids, were beneficially associated with the incidence, reversion and prevalence of MetS . No weight changes were observed among participants after 1-year intervention (Mayneris-Perxachs et al. 2014).
Finally, a review focused on the effects of selected nutrition models (Mediterranean, DASH, plant nutrition model) in humans on the concentrations of CRP and IL-6 and identified the Mediterranean diet as the most effective in inhibiting inflammation (Smidowicz & Regula 2015).

2.2. Nordic diet

A healthy Nordic diet, based on Nordic nutrition recommendation (Becker et al. 2004), and containing fish, rapeseed oil, whole-grain, high-fiber cereal products, berries, vegetables, fruits, nuts and low-fat dairy products (Bere et al. 2009; Adamsson et al. 2012) has been related to lower mortality (Olsen et al. 2011).
Low adherence to the NNR resulted in high salt consumption, high intakes of saturated fatty acids, low intakes of PUFAs and low dietary fiber (Jonsdottir et al. 2013).

The healthy Nordic diet seems to improve lipid profile, lowers blood pressure (Brader et al. 2014), and has a beneficial effect on low-grade inflammation (Uusitupa et al. 2013). The diet reduces inflammatory gene expression in subcutaneous adipose tissue compared with a control diet, independently of body weight change in individuals with features of MetS (Kolehmainen et al. 2015).
A dietary biomarker approach captured compliance and cardio-metabolic effects of this diet in individuals with MetS . Several of these dietary biomarkers were assessed and reflect different key components in the healthy Nordic diet: serum phospholipid α-linolenic acid (canola oil), eicosapentaenoic acid and docosahexaenoic acid (fatty fish), plasma β-carotene (vegetables) and

plasma alkylresorcinols (whole grains). High-fat dairy intake (expectedly low in this diet) was reflected by serum pentadecanoic acid (Marklund et al. 2014).
Docosahexaenoic acid (DHA, 22:6 n-3) in whole blood, an indicator of DHA and fish intake, seemed to be the main diet-relatd predictor of the beneficial effect of school meals based on the New Nordic Diet (Andersen et al. 2014), on MetS (Damsgaard et al. 2016). However, the school meals do not affect the MetS score in 8-11-year olds, as small improvements in BP, TG concentrations and insulin resistance were counterbalanced by slight undesired effects on waist circumference and HDL-cholesterol concentrations (Damsgaard et al. 2014).

The increased vitamin D intake does not result in higher plasma 25(OH)vitamin D concentration. The reason why this fish-rich diet did not improve vitamin D status might be that many fish are farmed and might contain little vitamin D. Frying fish may also result in vitamin D loss, due to fat extraction (Brader et al. 2014).

2.3. DASH-diet

A DASH-diet, a dietary intake to stop hypertension and maintain the current body weight, contains high amounts of fruit, vegetables and low-fat dairy products and is low in saturated fats and cholesterol, with a 2.4 g Na restriction (Azadbakht et al. 2005).
Consumption of the diet for 6 weeks reduced circulating levels of hs-CRP in serum. Other inflammatory markers (TNF-α, IL-2, IL-6 and adiponectin) were not affected (Saneei et al. 2014).
A decrease in total cholesterol and LDL-cholesterol concentration were observed (Roussell et al. 2012).
A higher-fat, lower carbohydrate modification of the DASH-diet for 3 weeks lowered blood pressure to the same extent as the DASH-diet, but also reduced plasma triglycerides and VLDL, without significantly changing LDL-cholesterol concentration (Chiu et al. 2016).

2.4. Vegetarian diets

According to the American Dietetic Association, a vegetarian diet is defined as a diet that does not contain meat or seafood, or products containing those components (Craig et al. 2009). More specifically, Bradbury et al 2014 defined vegetarians as people consuming also dairy products and/or eggs but no meat or fish. In this way they can be considered as ovo-lactovegetarians (Chiang et al. 2013), in contrast to the so-called vegans, which exclude all animal products.
Further on the term "vegetarians" includes all groups, exclusive the omnivores. Dividing them into various subgroups is very hard, since there are not only various groups and definitions, but also there is no sharp-cut distinction between those subgroups.
In Table 3 most vegetarian diets are summarized with some characteristics.

Besides these described types, other terms are mentioned in literature: "moderate adherence to the pro-vegetarian diet "(Pimenta et al. 2015), "strict raw food diet" (Koebnick et al. 2005) and, "su vegetarians" (people who adopt a vegetarian diet, but also a lifestyle that is very different from omnivores; Huang et al. 2014). Even geographic differences in the vegetarian diets are reported (Huang et al. 2011).

We intend to divide the vegetarian diets, as far as clear characteristics were traceable, into three groups: veganistic or restricted vegetarians, ovo-lacto vegetarians and the broad group of vegetarians.

2.4.1. Vegan diets

Vegan diet is most of the time used as a synonym for the restricted vegetarians (De Biase et al. 2007) Table 4 summarizes the influences of vegan diet on biomarkers of the MetS.

Quite remarkable is a lowered HDL-cholesterol concentration. This is not a beneficial change in a lipid profile related to the MetS (De Biase et al. 2007; Huang et al. 2014. Jian et al. 2015). A restrospective cohort study in Taiwan proved that a vegan diet did not decrease the risk of MetS. This study was carried out in comparison with pesco-vegetarian, lactovegetarian and non-vegetarian diets (Shang et al. 2011).

2.4.2 Ovo-lacto vegetarian diet

Only three publications could be traced in which the term “ovo-lacto vegetarians” was explicitely mentioned (Chiang et al. 2013; Huang et al. 2014; Jian et al. 2015). This type of diet was associated with a reduced risk for Met S, due to its lowering effect on LDL-cholesterol, despite of resulting in a lower HDL-cholesterol level (Chiang et al. 2013).

2.4.3. Vegetarian pattern

Some dietary components that are lower in the diets of vegetarians, such as energy intake, saturated fat, haem iron, and red and processed meat, may influence metabolic risk. In addition, plant-based diets are richer in fruit, vegetable, and fiber, which are protective against the development of MetS (Turner-McGrievy & Harris 2014).

A review of the literature proved that the majority of the studies, conducted mostly in Asian populations, revealed lowered risk of MetS among individuals following plant-based diets, as compared with an omnivorous population (Turner-McGrievy & Harris 2014).

Table 5 summarizes the influences of vegetarian diets on biomarkers of the MetS.

From this table 5 it can be concluded that vegetarian diet resulted in a better lipid profile, only a lowered HDL-cholesterol was registered (Koebnick et al. 2005; Sebekova et al. 2006; Chen et al. 2008; Gadgil et al. 2014; Chiu et al. 2015). Lower inflammatory markers (e.g. CRP, Lp-PLA2)(Chen et al. 2008; Chen et al. 2011; Krajcovicova-Kudiackova et al. 2011), lower markers of oxidative stress (ferritin; Kim & Bae 2012), but also a higher homocysteine level (Koebnick et al. 2005; Krajcovicova et al. 2011; Chen W et al. 2011; Obersby et al. 2013), probably due to low vitamin B12 content of the vegetarian food (Obersby et al. 2013) are published.

These conclusions are enforced by reviews of published observations (Orlich & Fraser 2014; Sabaté & Wien 2015) and the observation that dietary acculturation (reduction in vegetarianism, an increased intake of caffeinated drinks, and altered meal patterns) may be associated with the higher prevalence of MetS in migrant South Asians in the UK (Garduno-Diaz et al. 2013).

3. Various less-characterized diets

Table 6 summarizes some less-characterized diets and their influences on biomarkers of the MetS. Type and scarce specifications are included, as far as could be traced.

A multifunctional diet is characterized by a combination of low-glycemic-index meals, soybean and soy-protein-containing products, almonds, whole barley kernel products, plant stanols, fatty marine fish as source of long-chain ω-3 fatty acids, foods and ingredients rich in natural antioxidants and soluble dietary fiber. This decreased blood lipids and improved several other aspects of the cardio-metabolic risk profile in healthy overweight and obese subjects. The effect was not dependent on weight loss (Tovar et al. 2015).
Sometimes the expression “fast food” is mentioned for a high fat and protein-rich diet, with low phytochemical and low fiber products. Higher consumption of this food had undesirable effects after 3-years follow-up in Iran (Bahadoran et al. 2013; Marlatt et al. 2015; Asghari et al. 2015). Also postprandial oxidative stress (markers: plasma oxygen radical absorbance capacity, TBARS, MDA, lipid peroxide concentrations) was observed (Devaraj et al. 2008).

Ultra-processed food (Tavares et al. 2012) and breakfast-skipping (frequently together with inadequate sleep duration) (Marlatt et al. 2015; Kim et al. 2015) seemed to be associated with an enhanced risk of MetS.

Conclusion

Literature data on the effect of diet type or food pattern on biomarkers revealed that drawing definite conclusions is hampered by the fact that the description of food and nutrient consumption is not detailed enough. The heterogeneity of a certain type of diet cannot be stressed enough.
This is quite well illustrated by the large vegetarian-spectrum dietary pattern (Frazer 2009).
All sub-types of vegetarians had lower likelihoods of abnormalities compared with non-vegetarians for most biomarkers, except for HDL-cholesterol and sometimes TG. The better metabolic profile in vegetarians can be partially attributable to lower BMI. Proper management of TG and HDL-cholesterol, along with caution about the intake of refined carbohydrates and fructose may benefit all aspects of the metabolic profile (Chiu et al. 2015).
Besides these major remarks, the degree of dietary adherence and associated weight losses (Dansinger & Schaeffer 2006), and other lifestyle factors (Williams et al. 2000), are key predictors of MetS reduction.

Three dietary patterns emerged from this review as having promising features on biomarkers of the MetS: dietary approach to stop hypertension (DASH), a Nordic diet and especially the Mediterranean dietary pattern. Potential contributors to their beneficial effects on prevalence of MetS and influencing biomarkers are: fruits, vegetables, whole grains, dairy and dairy components, calcium, vitamin D, and whey protein, as well as monosaturated fatty acids, and ω-3 fatty acids (Calton et al. 2014).
A recent meta-analysis proved that consumption of the mentioned healthy dietary patterns resulted in significant reductions in C-reactive protein levels, while non-significant changes were found for all other biomarkers (Neale et al. 2016).

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