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Influence of Gut Microbiome on Obesity in Western-Style Dietary Practices Versus Other Diets: A Systematic Review

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Influence of Gut Microbiome on Obesity in Western-Style Dietary Practices Versus Other Diets: A Systematic Review

Cover Page Footnote
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Running Head: INFLUENCE OF THE GUT MICROBIOME ON OBESITY

The gut microbiome has a synergistic relationship with the human host (1). The gut houses over a trillion microbiota that work together to promote homeostasis within the body. The microbial community within the human gut are comprised of two dominating phyla, *Firmicutes* and *Bacteriodetes* (1). Colonization of the human gut begins with childbirth and vaginal birth reflects the colonies of bacteria like the mothers. Comparatively, a baby born by C-section is exposed to bacteria derived from human skin contact from medical practitioners handling the infant. The first three years of life are critical in establishing the gut flora as early exposure will reflect the adult gut microbiome later in life (2).

According to Shreiner et al. (2015) the microbiome contributes to many metabolic functions, fights against pathogens that attack the body, and influences the function of other physiologic processes (3). There are many environmental factors and behavioral practices that negatively influence the microbiome. The western-style dietary practices of American culture consisting of high-fat, high-fructose components have been shown to destroy the gut microbiome and lead to negative health outcomes (4). This systematic review aims to differentiate the impact of a Western diet on gut health verses a plant-based diet.

The human microbiome has sparked interest in research to investigate the vast alterations that are created by environmental conditions such as dietary intake resulting in adverse health effects. Much of the literature reviewed indicates that dietary changes alter the balance of the microbiome and may result in negative health outcomes associated with obesity, cardiovascular disease, chronic kidney disease, irritable bowel disease, and cancer (5). Therefore, understanding the influence of diet on the microbiome gives researchers the opportunity to target interventions to specifically improve ratios of health protective bacteria within the gut (6).

Method

California State University, San Bernardino, EBSCOHost library databases and Google Scholar inclusive of CINAHL plus, ScienceDirect, and PubMed were searched using keywords: “health outcomes,” “microbiome,” “plant-based diet gut microbiome,” “vegan diet and gut microbiome,” “obesity microbiota vegan diet,” and “vegan diet microbiome” to determine health effects of Western diet verses plant-based diet and health outcomes. Search results yielded 159 various articles. Some search criteria were narrowed to peer reviewed articles published within the past 20-years. Articles were selected based on population, intervention, comparison, and outcome (PICO) criteria specific to the topic of interest after abstracts were reviewed to determine qualifications to select 38 articles relevant to dietary impact on microbiome and obesity related health outcomes. Additional searches were conducted using EBSCOHost with the keywords: “Western-style

diet," "obesity," "gut microbiome," "gut microbiota," "plant-based diet," "Western diet," "alternative diets," "vegan diets," "vegetarian diets," "high fructose," and "high fat diet" resulting in a total of 93 search articles related to dietary impact on the health and function of human microbiome. Abstracts were reviewed to select articles that enabled comparison of plant-based diets, Western diets and mixed diets. All articles selected were in the English language, scholarly reviewed, and of more recent research (within ten to twenty years) to enable comparison of dietary impact on gut health. There are no existing protocol and systematic review registration factors utilized in this systematic review.

Results

Diets and Human Gut Microbiome

Diet as a fundamental part of life has evolved over hundreds of years and the types of food that humans are exposed to has a direct impact on the gut microbiota. Humans and microbes have a symbiotic relationship as the gut microbiota maintains homeostasis of the metabolic and physiologic processes that affect the human body (2) (34). Humans have become dependent on gut flora to synthesize various byproducts and nutrients from otherwise indigestible foods. Some of these processes include absorption of short chain fatty acids, vitamin K, and biotin that are necessary for metabolism. Diet is a modifiable factor that can cause a rapid response in microflora within 24 hours of ingestion of a new diet such as Western or Plant-Based diets. (34)

Additionally, diets influence the diversity of the gut microbiota (34)(2)(39). An increase in high-fiber diets like the Mediterranean, vegan, and vegetarian diets, act as prebiotics that nourish the gut microbiota, furnishing an extraordinary diversity of bacterial residents in the gut. Equally important is the fiber deficit within the Western diet, which impacts the low variation of gut microbiomes. The Western diet diminishes the availability of substrates for fermentation by the gut, essentially starving the resident bacteria (1). Arduous conditions in the gut leave the microflora without sustenance, which compels the bacteria to consume the mucus lining of the gut, thus weakening the protective barriers (37). This can generate malabsorption and chronic conditions such as leaky gut, proliferating susceptibility, and allowing permeation of pathogenic bacteria into the gut and the body. Modifying an individual's diet is perhaps the simplest form to aid in augmenting the diversity in microbiome and reducing the adverse health risks associated with low diversity in the gut. However, there is much debate on growth of new bacteria or possible evolution of current residents within the gut when exposed to new diets.

Literature found in this systematic review indicate that high fiber diets play a key role in establishing the diversity of the human gut microbiome. High

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

fiber diets are inclusive of prebiotic diets, which consists of fruits, vegetable, and plant-based proteins that contain an abundance of insoluble fibers influencing the growth of various bacterial species that can ferment the different types of substrates (35). In addition, exposure to a diverse medley of fruits and vegetables increases the content of microbiota that can ferment the substrates. A study by Wu et al. (2016) stated that early exposure of a fibrous diet may be necessary to observe variations within the gut microbiome (35). Additionally, the authors specified that the differences in the gut may take a significant length of time to reflect the variances.

A total of 252 articles resulted from the keyword searches from the previously mentioned databases. Of that number, 38 articles were selected after review of abstracts to include in this study. Each article was then read and reviewed to better understand the impact of diet on microbiome function in health. Articles that did not mention diets in relation to microbiome were excluded from the study to maintain the purpose of understanding dietary impact on microbiome health research question.

Data for systematic review articles selected for diet relevance are included in the appendix. Table 1 summarizes the articles reviewed regarding mixed diets, plant-based diets and Western diet. Participants range from adults and children to mice. Relationships between plant-based diets and the Western diet were observed in studies based in the United States, China, Australia, Korea and Greece. Studies comprised of mixed populations, ages eighteen and older, and number of participants varied from fourteen to over 22,043. Results were measured by interviews, observed behaviors, such as breastfeeding, adolescent food choices, parenteral influences and environmental impacts, as well as surveys that participants did or actual diets that were followed by a chosen group, which measured dietary intake of vegan, vegetarian, and omnivores (2,17, 19, & 39). Table 2 shows comparisons between mixed diets, plant-based diets and Western diets. Similar composition of participants was noted as above. More studies were found for plant based or mixed diets. Limited articles for Western diets were found and were limited to studies with mice and systematic reviews. Western diets showed an increase in inflammation with insulin resistance and increased obesity rates (25). Plant base and mixed diets showed positive correlations of a healthier gut microbiome (40). Reduction of inflammation and BMI were also observed within these vegan/vegetarian vs omnivore diet Vegan and vegetarian diet demonstrated a reduction in TMAO production, less inflammation, reduced heart disease vs the omnivore participant and increased TMAO production along with increased incidence of heart disease (1). Table 3 showed emerging trends found among plant based and mixed diets where a move diverse microbiome resulted from a more variety based dietary intake (40). Different diet types were found to alter microbiome which can lead to obesity (4,23). The Western diet also

changed the composition of gut flow due to obesity (23). Diverse cultural and dietary patterns were also shown and thus, should be a consideration for further research.

Trends found among Diets

The Western diet diminishes the availability of the substrates available for fermentation by the gut, essentially starving the resident bacteria (1). Trends found among Western-diet search articles included increased obesity of participants, increased inflammation of the body and less variety in diet. These negative trends were displayed in test mice, women, and men. In comparing exposure, The Western-diet is more influential in promoting poor microbiome health than BMI and social influences. It was found that Westernization of diet practices was a strong predictor of dieting consumption, but some cultural context differences did explain variances in diet behaviors (7). Some articles included systemic reviews that were used to find evidence of Western diet effects on people, but the research in these articles was more behavior based (40,17, 13). Although having controlled studies with mice provided support to show significant findings of diet effects, (it is not an exact replica of the human body (28, 25). This comparison was still needed since the field is new and limited data exists for human studies (18,4). The Western diet was found to lead to many health risks and higher obesity rates among people. Animal based diets did show an increase abundance of bile tolerant microorganisms (8).

Comparatively, plant-based diets, mixed diets, and pescatarian diets were positive in terms of health effects related to microbiota. When these types of diets were followed, microbiome composition was noted to influence gut regulation in a positive manner. Reduction of body inflammation was noted through testing of anti-inflammation markers. Plant based diets were found to yield the healthiest gut by increase organisms that maintain gut health (13,18). Plant based diets analyzed were vegan, pescatarian, Mediterranean and vegetarian. Mediterranean diets were found to have significant reduction in total mortality. (9) When viewing vegetarian and pescatarian diets against the Western-diet, research found that individuals who did not consume meat had better dietary intakes of micronutrient rich fruits and vegetables and reduced smoking rates (10). Some research indicate that vegetarians had greater variety in their diets and thus higher amounts of *Bacteroidetes* related operational taxonomic units (OTUs) (11). Vegan diets were found to be the most restricted diet, having the lowest total caloric energy intake, healthier fat intake, and lowest protein intake (12). Plant based diets yielded the healthiest gut, with increased energy and overall improved health.

Overall, most of the studies were based in the United States and had an average number of 100 participants. When comparing studies by countries or

region some patterns emerged such as social and cultural diets showing significant differences. In comparing diets, distinct differences were observed among the microbiota (13). Gut microbiota was also found to be mediated by differences in diet and other environmental factors (14). Healthier dietary patterns and behaviors as defined by nutrient rich variety intake and reduced fat and protein intake were observed in countries that did not follow the Western diet (15).

Initial Exposure to Gut Microflora

The foundation of the gut microbiome begins with the first few years of life. Development of the gut microbiota takes place during the birthing process. A baby that is born vaginally is introduced to the mother's colony of bacteria, consisting of *Lactobacillus* and *Prevotella* that are derived from the two dominant bacteria *Bacterioidetes* and *Firmicutes (*2*).* Introduction to the mother's microbiome is imperative as this is the first exposure the baby will have in microbiota development which will continue to flourish throughout the first three years of a newborn's life and reflect his/her microbiome in adulthood.

Breastfeeding is the earliest form of diet that impacts the child's gut flora. It is indeed the optimal form of nutrition for the infant, as it is all encompassing of profound nutrients such as immunoglobulins and human oligosaccharides (HMOs). HMOs are considered the first food for the gut microbiome because they are not digestible by the small intestine and travel to the colonic bacteria for processing. HMOs act as the earliest form of prebiotic, promoting growth of specific species within the gut (2). Differences between breast-fed infants and formula fed infants also reveal changes in gut microbiome. For example, a breastfeed infant's microbiome consists of aerobic and facultative microbes compared to a formula fed infant's that consists of anaerobic bacteria (2). These aerobic and facultative properties do not exist in the formula-based product which leads to differences in gut flora of formula fed infants compared to breastfed infants. Formula can therefore be considered a form of modern nutrition for an infant and be considered as the first exposure to a Western diet. As the child develops within the first three years of life, exposure to a variety of complex carbohydrates, fibers, plant-based proteins, fruits, and vegetables is essential in the early stages, because it will determine the foundation of the gut flora into adulthood (16).

Environmental Influence on Western-Style Dietary Practices

Western culture dietary practices are influenced by high-fat, high-calorie, and high-fructose foods. Western society is constantly surrounded by fast-food chain restaurants and diners, and most foods in the grocery store come packaged and preserved. Influences on food choices and preference of eating fast foods over

eating in-home is something that occurs daily. Not much thought is given to how these food choices and food intake affect the gut microbiome and the negative health outcomes it causes. A study by Pinard et al. (2014) noted that Western diet practices are influenced by food choices made at a young age (17). Parental influence on children acts as a critical component regarding the types of food and soft beverages children receive at restaurants. Decision making when dining away from home is often more liberal than at home practices. The study noted that Spanish-speaking parents tended to eat out fewer times a week, watched less television, and cooked more healthful meals at home due to specific cultural practices (17). Parental role modeling was noted to play a critical role in shaping how children will eat when reaching adulthood and the nutrition food knowledge of parents predicts the home environment for the child (17).

A Westernized diet that is higher in fat results in inflammation of metabolism mechanisms conducted by gut microbiome. The normal gut flora that are protective of health assist the body in digestion of foods, however when food intake is calorie dense, high in fat and high in polysaccharides, dysbiosis within the microbiome occurs (18). A high-fat diet results in inflammation mechanisms that stimulate endotoxin production in gut flora to deposit and store lipids more rapidly (18).

The overall goal for balance in microbiome is to have a ratio of less *Firmicutes* compared to *Bacteriodetes* because they produce simple sugars and increase insulin resistance mechanisms associated with type 2 diabetes mellitus (6). One study indicated that it only takes 24-hours to alter the microbiome and create more fat forming gut flora (19). Environmental implications that impact microbiome structure include: natural immune systems, environment the host thrives in, lifestyle choices, hygiene and sanitation factors and innate gene variations (20).

Food sources that are higher in fiber, and lower in fat and complex sugars protect the healthy bacteria that colonizes in the gut (13). One study found that a diet low in fat and low in carbohydrates improved the balance of microbiomes through protecting and encouraging the growth of healthy gut flora (21).

Therefore, researchers need to understand the factors of social, biological and physiological influence on food choice to address microbiome health and reduce negative health outcomes (20). Racial disparities also play an integral role in food choice and lifestyle factors in microbiome balance. Access to healthful fibrous foods in urban environments are important factors to consider in maintaining healthy microbiome.

Additionally, a diet that consists of variations in probiotics and prebiotics have shown promise in treating negative health outcomes associated with imbalanced microbiome. Some probiotic and prebiotic diet changes aid in restoring normal gut flora, but the best practice found to combat obesity is a

complete change of microbiome itself through gastric bypass surgical procedure and or fecal transplants (22). One study found that use of increased probiotic intake after gastric bypass surgery enhanced weight loss and improved microbiome balance in patients (23). Further research is necessary to address variations in data regarding prebiotic and probiotic uses in treating imbalanced microbiome.

Western Diet Effects on Microbiome and Obesity

Western dietary practices affect overall function of the gut microbiota, often leading to obesity and chronic health related effects. Hankinson et al. (2012) indicated that diet composition and activity behaviors such as television viewing time, sedentary activity, and physical activity levels were similar between obesity phenotypes (24). Activity level and its relationship to high calorie intake from Western diets relevant in assessing how Western dietary practices affect obesity and metabolic functions related to obesity because sedentary activity and high caloric intake can increase risk for obesity development. In assessing the specific Western diet factors that affect obesity, an article by Rosas-Villegas et al. (2017) determined that sucrose and fructose components, in addition to high-fat components negatively modify the gut microbiota, activating inflammation which can lead to health consequences such as insulin resistance and renal disease related to obesity (25).

The study by Volynets et al. (2017), described how an imbalance in gut microbiota leads to gut permeability, thus increasing the circulation of lipopolysaccharides which lead to obesity. An article by Chen et al. (2014), emphasizes how gut microbiota is heavily linked to long-term dietary styles, signifying why microbiota is different in other cultures (26). However, for Western culture where fast-food plays a staple role and obesity is common, the gut microbiota is higher in *Firmicutes/Bacteroidetes* and less bacterially diverse, affecting the host's metabolism. A study by Brozinick et al. (2013) demonstrated how Western dietary practices influence the synthesis of ceramides, a lipid-containing polysaccharide, to reduce insulin sensitivity and increase obesity rates (27). This is clearly similar with the findings reviewed by Volynets et al. (2017) in which Western dietary practices were studied among rats and indicated an impairment of the intestinal barrier, liver degeneration, and body weight gain, because both studies yielded impairment and weight gain (4).

Pfalzer et al. (2015) showed that diet and obesity are strong modulators of the gut microbiome and agreed with findings that a Western diet increases *Firimicutes* and decreases *Bacteriodetes* (28). Poutahidis et al. (2013) described how eating a Western-style diet restructures the gut microbiome and accelerates age-associated obesity in mice, indicating a change in weight gain and obesity (29). Kavanagh et al. (2013) supported this evidence and revealed that Western-

style diets high in fructose rapidly cause liver inflammation and damage among primates (30).

A Westernized diet changes the diversity of the microbiome effecting negative health outcomes such as obesity and mental illness. Oddly enough similar effects in patients who overeat and those who restrict calories at the opposite end of the spectrum in bulimia and anorexia nervosa disorders (31). According to another study by Khanna and Tosh (2014), a poorly diverse microbiome is associated with increased risk for the bacterial infection *Clostridium. difficile*, irritable bowel syndrome, irritable bowel disease, growth of antibiotic resistant bacteria, obesity metabolism, food allergies, and mental health disorders such as mood disorder, anorexia, schizophrenia, autism, and narcolepsy (22). As gut flora communicates with the host's DNA, the brain receptors, including serotonin, and satiety levels are altered, creating a vicious cycle of obesity resulting in negative health outcomes. Western-style diets demonstrate high degradation in the overall function and stability of the gut microbiome due to the components that make up this diet. Future study is necessary to understand the correlation of microbiome alterations and development of negative health outcomes. In contrast to the effects of the Western diet, plant-based diets can induce the development of healthful gut microbiota.

Plant based, Vegetarian, and Vegan Diet

As opposed to the Western-style diet, plant-based diets are high in plant proteins, fruits, vegetables, and legumes which work to increase the diversity of the human gut flora and contribute to an increased volume of bacterial metabolites such as short chain fatty acids (SCFA) that are an energy source for the colon and enhance colon health. In comparison to a Western diet, a Vegan diet produces copious amounts of metabolites that can be metabolized by the human body. According to Luongo et al. (2017) SCFA contribute to the stability of the inherent immune system of the human host increasing mucosal resistance against other pathogenic bacteria (32). Overall, this contributes to the health of the human host, providing protection from various chronic conditions.

As stated by Clark et al. (2017) a plant-based diet increases insulin sensitivity, influencing the uptake of glucose by the cells and promoting stabilization of blood glucose (33). Comparatively, a high glycemic load diet such as the Western diet contributes to overproduction of insulin by the pancreas, causing insulin resistance and supporting an inflammatory condition in the body. The study by Albenberg and Wu (2014) stated that a diet high in fruits, vegetables, and fiber contributed to differences in variations within the gut microbiota, increasing human health (2). This is not reflected in the Western diet, which correlates to decreased diversity in the gut, increased obesity, dyslipidemia, and in inflammatory conditions. As stated by Wong (2014), individuals that

followed vegetarian diets with lifestyle changes such as increased physical activity, diet modifications, and calorie reduction demonstrated improvement in blood glucose control, a decrease in coronary heart disease, and decreased lipid levels (1). Furthermore, an individual consuming a vegan diet had a reduction in the inflammatory markers C-reactive protein and low-density lipoprotein (LDL) (1).

Additionally, diets high in carnitine, which is abundant in the Western diet, produce toxic byproducts such as trimethylamine (TMAO) (1). TMAO has been linked to adverse health conditions such as coronary vascular disease. Also noted was the decreased production in TMAO in vegetarians and vegans in comparison to traditional Western/omnivore diets (1). Further studies need to be conducted to determine the impact of plant-based diets in comparison to Western diets and its impact on the gut microbiome

Mediterranean Diet

The Mediterranean diet which consists of fruits, vegetable, complex carbohydrates, legumes, olive oil, fish, and decreased amounts of red meat is associated with improved health outcomes such as reductions in the occurrence of cancer, autoimmune conditions and inflammatory conditions like Crohn's disease (9). Sandhu et al. (2017), stated the composition of the gut reflects an increase in *Bacteroides* and *Clostridium phyla* within the Mediterranean diet (34). The diet also encourages an augmented quantity of SCFAs due to the abundant intake of high-fiber foods that is correlated with an improved diversity of the human gut microbiota. The Mediterranean diet also has many components that contribute to high amounts anti-inflammatory properties such as increased micronutrient intake and reduced intake of pro-inflammatory foods such as high protein Western diet foods that are also high in bad lipids, which support a reduction in inflammatory conditions. Furthermore, the diet supports a reduction in TMAO levels, like the vegan and vegetarian diets postulating protective barriers against inflammatory conditions (34). Further suggestions in research would be to conduct longitudinal random control trials to determine effect of various plant-based diets on gut microflora in comparison to the Western diet.

Probiotics in Diet

Probiotics are live quantities of organism cultures in food that demonstrate beneficial health effects on the human host (35). Probiotics are found in foods that have been fermented using various strains of live microorganisms such as *Lactobacilli*, *Streptococci*, and *Bifidobacteria*. These can be found in various foods such as yogurt, cheese, kimchi, and sauerkraut. To use bacteria as probiotics they are required to have beneficial effects on the human host and need to meet certain criteria for human consumption (36). Probiotics are transient bacteria that

pass through the gut and do not take up residence because many of the bacteria do not survive the harsh environment of the gut. Nonetheless, the transient bacteria aid in establishing a stronger barrier to ward off possible pathogenic bacteria, improving the immune system by providing a beneficial health outcome for the host (37).

The addition of probiotics to a diet has demonstrated positive health benefits such as reduction in chronic inflammatory conditions, Crohn's disease, and antibiotic-related diarrhea. Molinaro et al. (2012) found a reduction in weight in obese mice when supplemented with the probiotic *Lactobacillus casei* (38). Additionally, inflammatory conditions such as type 2 Diabetes Mellitus showed improvement when given *Lactobacilli(38).* Another study exhibited positive results in obese mice when supplementing *L. rhamnosus PL60* in which there was a reduction in weight and white adipose tissue. This demonstrated production of conjugated linoleic acid (CLA), which contributed to the anti-obesity effects through reduction of the uptake of fatty acids. Although there has been improvement in weight management through understanding the microbiome influence in mice studies, human studies continue to have inconsistent results and future research needs to take this into account when determining gut influence on weight management and health outcomes. Although probiotics may provide a positive influence in human health, it is imperative to review the content of probiotics carefully as the industry is not federally regulated. Fermentation has been used for hundreds of years to preserve food using non-pathogenic forms of bacteria. According to Sonnenberg & Sonnenberg (2017), probiotics in food are said to have improved outcomes when consuming the product through fermented foods such as yogurt, kimchi and sauerkraut in comparison to capsule form. However, the authors did state both forms of taking probiotics may have beneficial effects as it is an individualistic response.

Future regulations are needed from the Federal Drug Administration on the industries that distribute probiotics for consumption to the public. Additional studies are needed to understand the health impact of various probiotic strains. Researchers may also consider how probiotics in fermented food compared to probiotics in capsules affect human health and if one is superior to the other. Further studies are needed to thoroughly comprehend the health benefits of probiotics on human health to help ameliorate inflammatory conditions and other chronic diseases.

Discussion

Regardless of suggested dietary recommendations, researchers have shown that the microbiome has an impact on health outcomes. Obesity is a critical factor in microbiome balance and consumption of prebiotic/probiotic in diets are thought to

stimulate healthy gut flora, but data is inconsistent due to alterations in probiotic uses and individualized reactions (23). This research suggests that a diet lower in fat and sugar and higher in fiber can aid in protecting normal gene expression and prevent disease processes (19).

Limitations of Studies

The majority of studies were based in the U.S., so a weak international connection was noted. The changes of sample size also posed a challenge in determining if significant results existed in studies. Since diverse populations exist, incorporation of different methods and study designs will be needed to show effective trends. Additionally, although some strong negative and positive findings were noted with the Western diet, some limitations existed within these studies as; many of the studies conducted were animal trials using mice compared to the limited research that involved human subjects.

Implications for Future Studies

The literature shows inconsistency with respect to the ratio of specific obesity inducing bacteria in gut flora. This indicates a need for further research and understanding of microbiome mechanisms in health (40). Cause and effect relationships in microbiome function and health are still unclear with respect to what circumstances alter microbiome function from helpful to pathogenic processes (5). Further controlled studies with humans need to be expanded to gather data in this field. Diverse views of foods can also be affected by participants exposure in different countries' media and educational systems (41). Future focus in microbiome research should include; creating a foundation of healthy eating patterns that enhance nutrition science, diet and food choices, agricultural systems, the environment, and human health (15).

Conclusion

Understanding disease processes associated with variations in microbiome can help researchers target interventions to maintain positive health status. Knowledge that the internal and external environment is continually impacting gut flora from conception to infancy, adolescence, and end of life stages is important (22). The microbiome relationship to disease processes is complex and requires continued research in the direction of mapping disease processes and microbiome influences from dietary intake and environmental changes to better understand and treat public health areas of concern.

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INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Appendices

Table 1: Summary of Articles

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Diet Composition and Activity Level of At Risk and Metabolically Healthy Obese American Adults	Hankinson, A.	2012	To determine if Western diet composition and/or physical activity affect metabolically healthy obese population phenotypes	Metabolically healthy obese Americans	Men n=398 Women n=377	Diet composition and activity behaviors were similar between obesity phenotypes
Science and Technology: Hard to stomach; Health and Gut Bacteria	Anonymous (45)	2010	To determine how Western diet practices, affect gut bacteria on children	Children	29 Children	A Western diet promotes unhealthy gut bacteria in children
The gut microbiome profile in obesity: a systematic review	Castaner, O.	2018	Find relevant evidence of associations between microbiome and obesity and discover variations after	Literature	Systematic Review	Relationship shown between diet type and alterations to microbiome resulting in obesity. the microbiome is different, but results are inconsistent across studies regarding microbiome ratios in obese verses lean individuals

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
			weight loss surgery			
The human gut microbiome	Sweeney, T.	2013	Update care providers on new research regarding microbiome and understanding changes after weight loss surgery	Obese adult humans, mice, human twins	9-124 Participants	Westernized diet changes the ratio of gut flora to induce obesity through increased efficiency in energy production, use of probiotics after weight loss surgery encourages good gut flora to grow and increases weight loss
Insights into the role of the microbiome in obesity and type 2 diabetes	Hartstra, A.	2015	Determine impact of weight gain and dietary habits on microbiome changes	Literature	Literature Review	Microbiome communications resist weight loss attempts causing obesity to be more than a lifestyle choice but a diagnosable disease. Fecal transplants show promise in reducing insulin resistance and obesity, but research is inconsistent in this area. However, low fat, low carbohydrate diets, diets high in prebiotics and probiotics, and

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
						better control of antibiotic use show improvements in quality of microbiome for weight maintenance
Gut microbiome, obesity-related comorbidities, and low-grade chronic inflammation	Tarantino, G.	2014	Explore mechanisms of various diets on gut microbiome	Mice	N/A (Editorial)	High fat diet results in inflammation mechanisms and stimulated endotoxins produces in gut flora to deposit and store fat more rapidly
A clinician's primer on the role of the microbiome in human health and disease	Khanna, S.	2014	Introduce concepts of microbiome research and explore diseases associated with variations in microbiome	Primarily internal medicine physicians and authors	N/A	Some probiotic and prebiotic dietary therapies aide in restoring good gut flora but the best practice is fecal transplant to decrease disease processes such as C. Diff, IBS, IBD, Antibiotic resistant bacteria, obesity metabolism, allergies, and mental health disorders. However, results are inconsistent in research and therefore more is needed to determine effectiveness of prebiotic type

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
						used and individual reactions to therapies.
Gut microbiome imbalance: pathways to weight gain and illness	Mullin, G.	2015	Understand gut flora effect of weight gain	Obese	12	Low fat and low carbohydrate diet altered flora type. Better understanding of gut flora communication with DNA to alter gene expression based on dietary intake. High fiber diet protective effect and reduced inflammatory metabolic processes.
Health Disparities and the Microbiome	Findley, K.	2016	Design a framework to research microbiome changes resulting from disparities in various racial ethnic groups	African American, Hispanic, Native Americans	Manuscript	Microbiome adaptations vary based on environmental exposures such as access to foods in lower socioeconomic areas increasing chronic conditions such as diabetes and colorectal cancer among the black population. for example, the microbiome varied based on geographic location and diet

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
						differences in high fiber and high fat intakes
Exposure to Westernization and Dieting: A Cross-Cultural Study	Gunewardene, A.	2008	The study focused whether index of exposure to Westernization would predict dieting behavior above BMI and social influences. Diet behaviors were compared among teenagers from different cultural backgrounds.	China and Australia	101 females (Beijing, China), 60 females (Chinese heritage living in Sydney, Australia), and 100 female Australians (no Chinese background)	Westernization index was a powerful predictor of dieting, differences in cultural context account for differences in dieting behavior. It was also found Australian girls' diet significantly more.

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Assessing the Influence of Vegan, Vegetarian and Omnivore Oriented Westernized Dietary Styles on Human Gut Microbiota: A Cross Sectional Study	Losasso, C.	2003	Study focused on impact of vegan, vegetarian, and omnivore feeding type on the compositionof gut microbiota.	Vegans, vegetarians and omnivores	101 individuals categorized as vegans (VG) (N = 26), vegetarians (V) (N = 32), and omnivores (O) (N = 43)	Vegetarians had a significantly greater richness compared to omnivorous. Moreover, counts of Bacteroidetes related operational taxonomic units (OTUs) were greater in vegans and vegetarians compared to omnivores.

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
The Netherlands Cohort Study – Meat Investigation Cohort; a population-based cohort over-represented with vegetarians, pescatarians and low meat consumers	Gilsing, A.	2013	Establish an analytical cohort over-represented with vegetarians, pescatarians and 1 day/week meat consumers, and to describe their lifestyle and dietary characteristics. Compare self-reported vegetarian's vs vegetarians confirmed by their response on the extensive food frequency questionnaire (FFQ).	Vegetarians, pescatarians and 1 day/week meat consumers	120,852	Vegetarians, pescatarians, and 1 day/week meat consumers had better dietary intakes (higher fiber/ vegetables) and lifestyle characteristics (e.g. lower smoking rates) compared to regular meat consumers in both sexes

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Adherence to a Mediterranean Diet and Survival in a Greek Population	Trichopoulou, A.	2003	Assess the relation between adherence to the Mediterranean diet and total mortality, as well as mortality due to coronary heart disease and mortality due to cancer, with adjustment for age, sex, body-mass index, physical-activity level, and other potential confounders.	Greeks following the Mediterranean diets	22043	Adherence to the traditional Mediterranean diet is associated with a significant reduction in total mortality

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
What Current Literature Tells Us About Sustainable Diets: Emerging Research Linking Dietary Patterns, Environmental Sustainability, and Economics	Auestad, N.	2015	Review the emerging research on environmental and related economic impacts of dietary patterns, including habitual eating patterns, nutritionally balanced diets, and a variety of different dietary scenarios	Review of Various Articles	REVIEW OF VARIOUS ARTICLES	Socially and culturally diverse dietary patterns are evident across the globe and within individual countries.
Cross-cultural comparison of perspectives on healthy eating among Chinese and American undergraduate students	Banna, J.	2016	Describe perspectives on healthy eating among Chinese and American young adults and identify similarities and differences	Chinese and American	Chinese (n = 55) and American (n = 57) undergraduate students in Changsha, Hunan, China and	Diverse views may reflect food-related messages to which participants are exposed both through the media and educational systems in their respective countries

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
			between these groups.		Honolulu, Hawaii, U.S.	
Comparison of the Gut Microbiotas of Healthy Adult Twins Living in South Korea and the United States	Lee, S.	2011	Compared the composition of the fecal microbiotas of Korean and U.S. adult twin	Korea and United States	85= European- and African-ancestry twin, 19= Korea Twin	Gut microbiota shows some signature of biogeography, potentially mediated by differences in diet and/or other environmental factors
Impact of diet and individual variation on intestinal microbiota composition and fermentation products in obese men	Salonen, A.	2014	Comprehensive and deep microbiota analysis of 14 obese males consuming fully controlled diets supplemented with resistant starch (RS) or non-starch polysaccharides	United States	15 subjects	Study diets induced clear and distinct changes in the microbiota.

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
			(NSPs) and a weight-loss (WL) diet.			
Diet rapidly and reproducibly alters the human gut microbiome	David, L.	2014	Studied how short-term consumption of diets composed entirely of animal or plant products alters microbial community structure and overwhelms inter-individual differences in microbial gene expression	United States	Six male and four female American volunteers	The animal-based diet increased the abundance of bile-tolerant microorganisms (Alistipes, Bilophila, and Bacteroides) and decreased the levels of Firmicutes that metabolize dietary plant polysaccharides (Roseburia, Eubacterium rectale, and Ruminococcus bromii)

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Comparison of Nutritional Quality of the Vegan, Vegetarian, Semi-Vegetarian, Pesco-Vegetarian and Omnivorous Diet	Clarys, P.	2014	Compare the quality and the contributing components of vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diets	United States	1476 participants	The most restricted diet, i.e., the vegan diet, had the lowest total energy intake, better fat intake profile, lowest protein and highest dietary fiber intake in contrast to the omnivorous diet. Calcium intake was lowest for the vegans and below national dietary recommendations. The vegan diet received the highest index values and the omnivorous the lowest for HEI-2010 and MDS
Comparative metabolomics in vegans and omnivores reveal constraints on diet-dependent gut microbiota metabolite production	Wu, G.	2016	Authors measured dietary intake, gut microbiota composition and the plasma metabolome between healthy human vegans and omnivores, sampled in an	Literature	Manuscript	It was found that plasma metabolome of vegans differed greatly from omnivores but the gut microbiota was similar.

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
			urban USA environment.			
The microbes we eat: abundance and taxonomy of microbes consumed in a day's worth of meals for three diet types	Lang, J. (43)	2014	Measured microbes in food content	Food	15 Meals	USDA recommended diet had most microbes in diet, followed by Vegan diet, then the American diet
Intrinsic association between diet and the gut microbiome: current evidence	Lang, K.(42)	2015	Diet association with microbiome	Literature	Manuscript	Gut microbiome can change overtime can activate various metabolic pathways that are unconnected to the changes of the microbiota community

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Dairy and plant-based food intakes are associated with altered fecal microbiota in 2 to 3-year-old Australian children	Smith-Brown, P.	2016	Diet was measured via food frequency questionnaire and 24-hour recall to associate food intake with microbiota composition	Australian children 2-3 years old	37	Identified that dairy and plant-based diets have a relationship with altered microbiota composition
Edible Plants and their Influence on the Gut Microbiome and Acne	Clark, A.	2017	How edible plants influence gut and acne	Literature	Review	Found plant-based food and probiotics are related to decrease in facial acne and systemic inflammation
Feeding the microbiota-gut-brain axis: diet, microbiome, and neuropsychiatry	Sandhu, K.	2017	Modulation of gut microbiota	Literature	Review	Diet composition and nutritional status are related to the regulation of gut microbiota composition
Diet and the Intestinal Microbiome: Associations, Functions, and Implications for	Albenberg, L.	2014	Agrarian plant-based diet	Literature	Manuscript	The effect of diet of human metabolome of the human gut microbiota and contributions to pathogenesis

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Health and Disease						
Gut microbiota and cardiometabolic outcomes: Influence of dietary outcomes: influence of dietary patterns and their associated components	Wong, J.	2014	Vegetarian and vegan diets	Literature	Review	Impact of diet on cardiovascular health and diabetes
Diet Effects in Gut Microbiome and Obesity	Chen, J.	2014	To determine diet effects on microbiome and obesity	Literature	Review	Diet affects the gut microbiome increasing obesity rates
Influences on Food Away from Home Feeding Practices Among English and Spanish Speaking	Pinard, C.	2014	Identified parental influence on food away from home and inside home,	English and Spanish Speaking Latino Families	Adults n=20, Children n=20	Feeding practices are influenced by parents at a young age

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Parent–Child Dyads			and restaurant ordering			
Dietary fructose induces endotoxemia and hepatic injury in calorically controlled primates1	Kavanagh, K.	2013	To assess high fructose, low fat (24% of calories) diet effect on obesity among primates	Monkeys	n=17	High fructose diet leads to liver inflammation
Intestinal Barrier Function and the Gut Microbiome Are Differentially Affected in Mice Fed a Western-Style Diet or Drinking Water Supplemented with Fructose1	Volynets, V.	2017	To determine how a Western diet and high fructose promote metabolic disease	Mice	n=12	Consumption of a Western, high fructose diet differentially affects gut permeability and microbiome and promotes weight gain
Diet- and Genetically-Induced Obesity Differentially Affect the Fecal	Pfalzer, A.	2015	To determine how Western diet and obesity affect the	Mice	n=40	Western diet leads to tumor forming tissue in mice

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Microbiome and Metabolome in Apc1638N Mice			microbiome in mice			
Diets in Transition: Hunter-gatherers to Station Diet and Station Diet to the Self-Select Store Diet	Smith, P. (44)	1999	To determine differences in transition from hunter-gather method to station. self-select diet	People	n>100	Distinguished differences between older dietary practices to more easily accessible food items
Microbial Reprogramming Inhibits Western Diet Associated Obesity	Poutahidis, T.	2013	To identify how Western diet affects obesity among rats	Mice	N=10-30	Western diet increased adipose tissue in mice
Differential Effect of Sucrose and Fructose in Combination with a High Fat Diet on Intestinal Microbiota and Kidney Oxidative Stress	Rosas-Villegas, A.	2017	To determine how high fat diet influences intestinal microbiota on rats	Rats	N=5-7	High fructose diet leads to deterioration of intestinal microbiota and leads to kidney disease

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Plasma sphingolipids are biomarkers of metabolic syndrome in non-human primates maintained on a Western-style diet	Brozinich, J.	2013	To determine how wester diet affects plasma of metabolism	Animals	N/A	High fructose diet induces synthesis of lipid producing proteins
The gut microbiome in health and disease	Schriener, A.	2015	To determine how gut microbiome affects health	Literature	Review	Identified host microbiome interactions in relation to health and disease
Gut Microbiota Modulation and Its Relationship with Obesity Using Prebiotic Fibers and probiotics: A Review	Dahiya, D.	2017	Investigate the variance between probiotic and gut microbiome in relation to obesity.	Literature	Review	Human/animal studies performed determined dysbiosis in the gut microbiome predisposes human/animals to obesity as well as other conditions.

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Table 2: Diet Types

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
Diet Composition and Activity Level of At Risk and Metabolically Healthy Obese American Adults	Hankinson, A.	2012	Western Diet	To determine if Western diet composition and / or physical activity affect metabolically healthy obese population phenotypes	Metabolically healthy obese Americans	Men n=398, women n=377	Diet composition and activity behaviors were similar between obesity phenotypes
Intestinal Barrier Function and the Gut Microbiome Are Differentially Affected in Mice Fed a Western-Style Diet or Drinking Water Supplemented with Fructose1	Volynets, V.	2017	Western Diet	To determine how a Western diet and high fructose promote metabolic disease	Mice	n=12	Consumption of Western style diet leads to gut permeability in microbiome
Diet- and Genetically-Induced Obesity Differentially Affect the Fecal Microbiome and	Pfalzer, A.	2015	Western Diet	To determine how Western diet and obesity affect the microbiome in mice	Mice	n=40	Lactobacilli bacteria demonstrated increased levels of anti-inflammatory markers vs. bifidobacteria in the omnivorous diet.

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
Metabolome in Apc1638N Mice							
Assessing the Influence of Vegan, Vegetarian and Omnivore Oriented Westernized Dietary Styles on Human Gut Microbiota: A Cross Sectional Study	Losasso, C.	2003	Western / Plant Base Diets	Study focused on impact of vegan, vegetarian, and omnivore feeding type on the composition of gut microbiota.	Vegans, vegetarians and omnivores	101 individuals categorized as vegans (VG) (N = 26), vegetarians (V) (N = 32), and omnivores (O) (N = 43)	Vegetarians had a significantly greater richness compared to omnivorous. Moreover, counts of Bacteroidetes related operational taxonomic units (OTUs) were greater in vegans and vegetarians compared to omnivores.
Impact of diet and individual variation on intestinal microbiota composition and fermentation products in obese men	Salonen, A.	2014	Various Diets	comprehensive and deep microbiota analysis of 14 obese males consuming fully controlled diets supplemented with resistant starch (RS) or non-starch	United States	14 subjects	Study diets induced clear and distinct changes in the microbiota.

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
				polysaccharides (NSPs) and a weight-loss (WL) diet.			
Gut microbiota and cardiometabolic outcomes: Influence of dietary outcomes: influence of dietary patterns and their associated components	Wong, J.	2014	Vegan Diet	Vegetarian and vegan diets	Literature	Review	Impact of diet on cardiovascular health and diabetes
Immune-modulating effects in mouse dendritic cells of lactobacilli and bifidobacteria isolated from individuals following omnivorous,	Luongo, D.	2017	Vegan Diet	Ovo lacto vegetarian and vegan diets, Measured lactobacilli and bifidobacteria and fecal samples	Healthy Italian volunteers	155	Lactobacilli bacteria demonstrated increased levels of anti-inflammatory markers vs. bifidobacteria in the omnivorous diet.

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
vegetarian and vegan diets							
Comparative metabolomics in vegans and omnivores reveal constraints on diet-dependent gut microbiota metabolite production	Wu, G.	2016	Vegan Diet	Authors measured dietary intake, gut microbiota composition and the plasma metabolome between healthy human vegans and omnivores, sampled in an urban USA environment.	Literature	Manuscript	It was found that plasma metabolome of vegans differed greatly from omnivores but the gut microbiota was similar.
The microbes we eat: abundance and taxonomy of microbes consumed in a day's worth of meals for three diet types	Lang, J.	2014	Vegan Diet	Measured microbes in food content	Food	15 Meals	USDA recommended diet had most microbes in diet, followed by Vegan diet, then the American diet

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
Diet rapidly and reproducibly alters the human gut microbiome	Winglee, K. (42)	2015	Vegan Diet	Association between diet and gut microbiome	Literature	Manuscript	Gut microbiome can change overtime can activate various metabolic pathways that are unconnected to the changes of the microbiota community
Feeding the microbiota-gut-brain axis: diet, microbiome, and neuropsychiatry	Sandhu, K	2017		Modulation of gut microbiota	Literature	Review	Diet composition and nutritional status are related to the regulation of gut microbiota composition
Diet and the Intestinal Microbiome: Associations, Functions, and Implications for Health and Disease	Albenberg, L.	2014	Agrarian plant-based diet	Agrarian plant-based diet	Literature	Manuscript	The effect of diet of human metabolome of the human gut microbiota and contributions to pathogenesis
Exposure to Westernization and Dieting: A Cross-Cultural Study	Smith-Brown, P.	2016	Plant based & Dairy	Diet was measured via food frequency questionnaire and 24-hour recall to associate food intake with	Australian children 2-3 years old	37	Identified that dairy and plant-based diets have a relationship with altered microbiota composition

Title	First Author	Publication Year	Diet	Measured	Target Population	N. of Participants	Findings
				microbiota composition			
Edible Plants and their Influence on the Gut Microbiome and Acne	Clark, A.	2017	Plant based	How edible plants influence gut and acne	Literature	Review	Found plant-based food and probiotics are related to decrease in facial acne and systemic inflammation

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Table 3: Trends Found Among Diets

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
Gut Microbiota Modulation and Its Relationship with Obesity Using Prebiotic Fibers and probiotics: A Review	Dahiya, D.	2017	Investigate the variance between probiotic and gut microbiome in relation to obesity.	Literature	Review	Human/animal studies performed determined dysbiosis in the gut microbiome predisposes human/animals to obesity as well as other conditions.
The gut microbiome profile in obesity: a systematic review	Castaner, O.	2018	Find relevant evidence of associations between microbiome and obesity and discover variations after weight loss surgery	Literature	Systematic Review	Relationship shown between diet type and alterations to microbiome resulting in obesity. the microbiome is different, but results are inconsistent across studies regarding microbiome ratios in obese verses lean individuals
The human gut microbiome	Sweeney, T.	2013	Update care providers on new research regarding microbiome and understanding changes after weight loss surgery	Obese adult humans, Humans, Mice, Human Twins	9-124 participants	Westernized diet changes the ratio of gut flora to induce obesity through increased efficiency in energy production, use of probiotics after weight loss surgery encourages

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
						good gut flora to grow and increases weight loss
Gut microbiome, obesity-related comorbidities, and low-grade chronic inflammation	Tarantino, G.	2014	Explore mechanisms of various diets on gut microbiome	Mice	N/A (Editorial)	High fat diet results in inflammation mechanisms and stimulated endotoxins produces in gut flora to deposit and store fat more rapidly
What Current Literature Tells Us About Sustainable Diets: Emerging Research Linking Dietary Patterns, Environmental Sustainability, and Economics	Auestad, N.	2015	Review the emerging research on environmental and related economic impacts of dietary patterns, including habitual eating patterns, nutritionally balanced diets, and a variety of	Review of Various Articles	Review of Various Articles	Socially and culturally diverse dietary patterns are evident across the globe and within individual countries.

INFLUENCE OF THE GUT MICROBIOME ON OBESITY IN WESTERN-STYLE DIETARY PRACTICES VS. OTHER DIETS

Title	First Author	Publication Year	Measured	Target Population	N. of Participants	Findings
			different dietary scenarios			
Comparison of the Gut Microbiotas of Healthy Adult Twins Living in South Korea and the United States	Lee, S.	2011	Compared the composition of the fecal microbiotas of Korean and U.S. adult twin	Korea and United States	85= European- and African-ancestry twin, 19= Korea Twin	Gut microbiota shows some signature of biogeography, potentially mediated by differences in diet and/or other environmental factors
Diet- and Genetically-Induced Obesity Differentially Affect the Fecal Microbiome and Metabolome in Apc1638N Mice	Pfalzer, A.	2015	To determine how Western diet and obesity affect the microbiome in mice	Mice	n=40	Western diet leads to tumor forming tissue in mice

Figure 1: PRISMA Flow Diagram