# Obesity & Energy Homeostasis Case study: Critical analysis & evaluation

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# Background

Obesity is a worldwide health epidemic with prevalence rates ever-increasing within Western societies. The number of adults that were overweight or obese in the United Kingdom was over half the population in 2017, with higher incidence in males compared to females (NHS, 2017). A trend of the current data shows no sign of slowing down, with rates that may reach close to 70% over the next 10 – 15 years (**Figure 1**). The prevalence of morbid obesity in the UK also appears to be following the same path, the rates of morbid obesity in England alone were 3% in 2018 and are projected to rise to 8% by the year 2035, putting a substantial financial burden on the health system (Keaver et al., 2018).

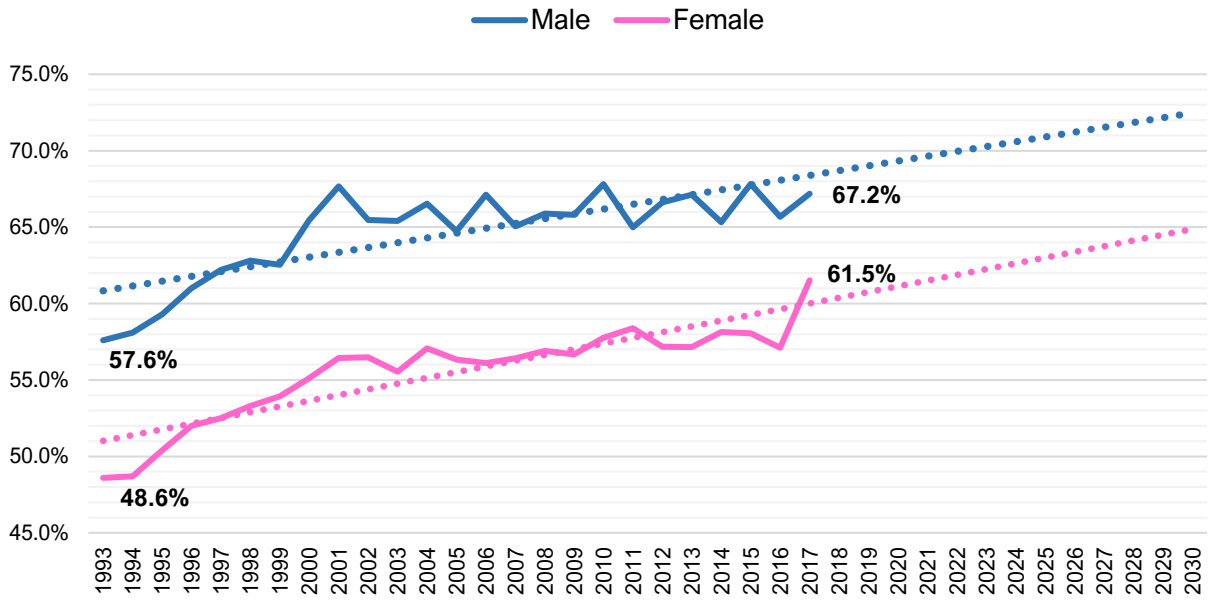


**Figure 1.** Prevalence of overweight and obese adults in England from 1993 to 2017, grouped by sex. A forecast of the trends up until the year 2030 are also displayed (NHS, 2017).

The health implications related to obesity are complex, they often manifest chronically and many of them are causally interlinked (Agha and Agha, 2017). Obesity can be defined as an abnormal accumulation of adipose tissue to the point at which it has an adverse effect on health (NHLBI, 2010). The relative risk of all-cause mortality and body mass index (BMI) classifications have been shown to be positively correlated, with being overweight having 30% increase in all-cause mortality, obesity class I with a 60% increase and obesity class II with a 110% increase (Agha and Agha, 2017). The life expectancy cost of individuals who are severely obese is said to be estimated between 5-20 years (Fontaine et al., 2003).

There are multiple comorbidities that are associated with being overweight and obese (Guh et al., 2009). An overview of the comorbidities associated with obesity can be seen in **Table 1** and **Figure 2**.

**Table 1**. Comorbidities associated with obesity

| Comorbidity | Reference |
|---|---|
| **Breast Cancer** | Carmichael and Bates, 2004 |
| | Engin, 2017 |
| | Lee et al., 2019 |
| | Picon-Ruiz et al., 2017 |
| **Pancreatic Cancer** | Bracci, 2012 |
| | Michaud, 2016 |
| | Xu et al., 2018 |
| **Gastrointestinal Cancer** | Donohoe et al., 2014 |
| | Frezza et al., 2006 |
| **Endometrial Cancer** | Soliman et al., 2008 |
| **Cardiovascular Disease** | Cercato and Fonseca, 2019 |
| | Kachur et al., 2017 |
| | Koliaki et al., 2019 |
| **Stroke** | Dehlendorff et al., 2014 |
| | Mitchell et al., 2015 |
| **Non-Fatty Liver Disease** | Holterman et al., 2013 |
| | Koppe, 2014 |
| | Polyzos et al., 2019 |
| **Diabetes** | Al-Goblan et al., 2014 |
| | Daousi et al., 2006 |
| | Wilding, 2014 |
| **Gallbladder Disease** | Bonfrate et al., 2014 |
| **Sleep Apnoea** | Lee et al., 2017 |
| | Romero-Corral et al., 2010 |
| | Schwartz et al., 2008 |
| **Chronic Back Pain** | Chou et al., 2016 |
| | Okifuji and Hare, 2015 |
| **Depression** | Chauvet-Gelinier et al., 2019 |
| | Gibson-Smith et al., 2018 |
| **Reproductive Disease** | Dağ and Dilbaz, 2015 |
| | Jungheim et al., 2012 |
| | Norman and Clark, 1998 |
| **Osteoarthritis** | King et al., 2013 |
| **Asthma** | Peters et al., 2018 |

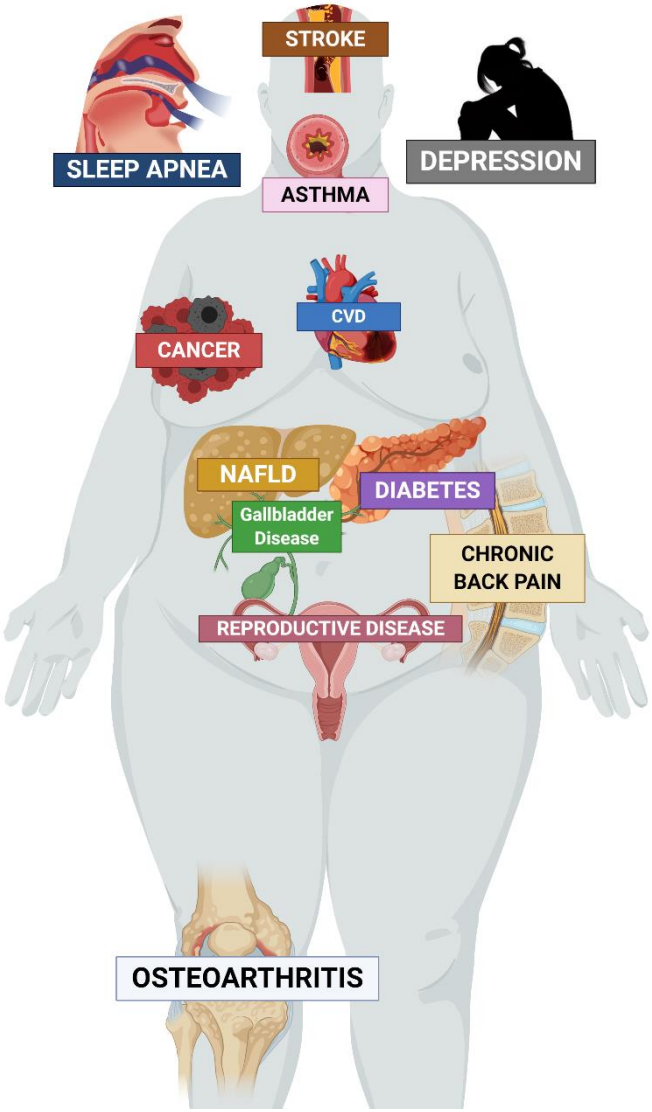


**Figure 2**. Comorbidities associated with obesity

Obesity is one of the top three global social burdens caused by humans. An estimated annual global economic impact is said to be around $2 trillion/year (2.8% of global gross domestic product), which is closely behind armed violence, war and terrorism and smoking, which are estimated at $2.1 trillion/year (Tremmel et al., 2017). Both the direct and indirect cost to the NHS in treating obesity—along with its associated consequences—has markedly risen since 1998 (**Figure 3**). The cost related to cardiovascular disease and stroke related to obesity, pose the largest burden to the NHS with a combined cost of 9.9 billion in 2015 (**Figure 4**).

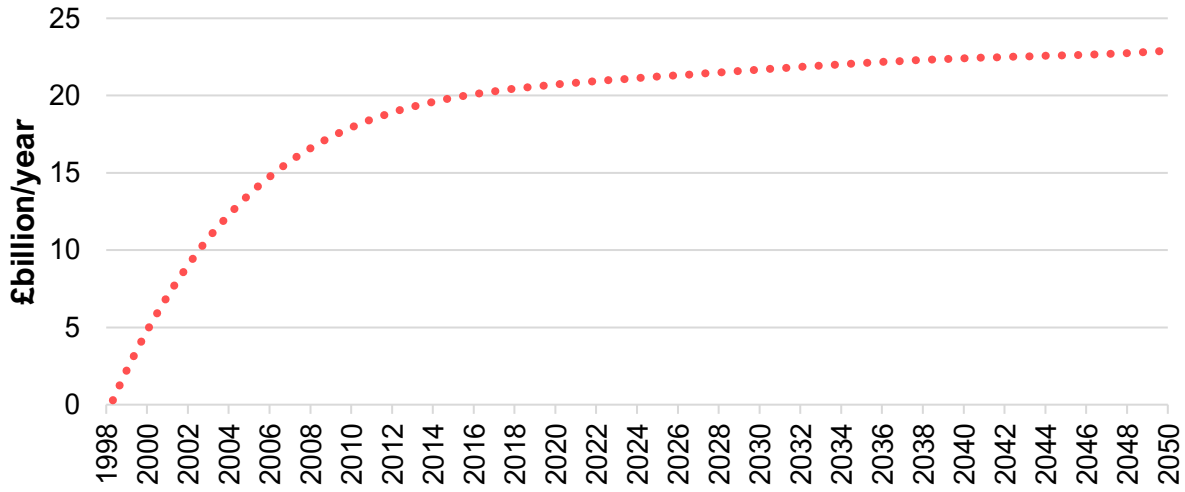


**Figure 3.** Estimated past, present and future cost to the NHS of diseases related to BMI, 1999 – 2050 (Agha and Agha, 2017).

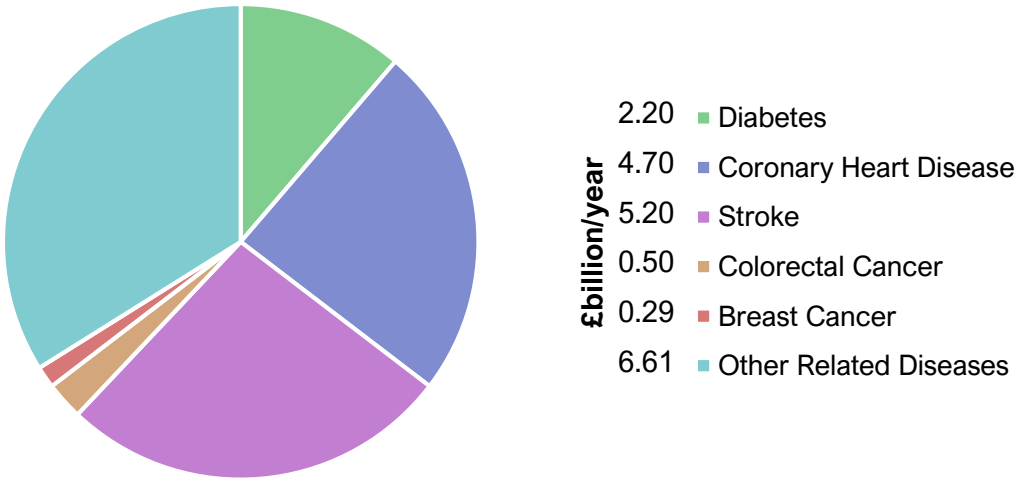


**Figure 4.** Estimated cost distribution to the NHS across common diseases related to BMI, 2015 (Agha and Agha, 2017).

This case report will investigate an obese individual's current health risk and perform a critical analysis of the lifestyle and diet they are following. Then highlight the areas that are contributing to any potential ill-health and provide evidence-based and realistic recommendations that will reduce future disease risk associated with obesity.

# The Participant

The participant is a 35-year-old female, who is married with two children. She has been overweight since adolescence and has suffered from mild depression from an early age, she also has a paternal family history of obesity, diabetes, depression and high blood pressure. The housework and childcare are predominantly carried out by the participant as her spouse works away, this influences her dietary habits, with a reliance on frozen products and pre-prepared meals. She also consumes more alcohol and cigarettes during times of stress, with regular consumption of cups of coffee throughout the day. The participants GP has advised that her blood pressure and cholesterol levels are high, she also complains of lethargy, tiredness and suffers from headaches. **Table 2** lists the participants details and anthropometrics.

**Table 2** – Participant details and anthropometrics.

| | |
|---|---|
| **Age** | 35 years |
| **Sex** | Female |
| **Bodyweight** | 95 kg |
| **Height** | 1.58 m |
| **Body Mass Index (BMI)** | 38.05 |

BMI calculated using equation in **Appendix 1.1**.

The participant weighs 95kg at a height of 1.58m, this equates to a BMI of 38.05 which is classified in the severe obesity class II category (**Table 3**). A systematic review and meta-analysis of 30.3 million participants investigated the relationship between BMI and relative risk of all-cause mortality. They found that a J-shape dose response relationship was representative in non-smokers and a U-shape dose response relationship was representative in current and former smokers (Aune et al., 2016). Due to the participant being a current smoker, data from 'current smokers' was used to estimate the participants estimated relative risk of all-cause mortality in relation to their BMI using a 2nd order polynomial regression (**Figure 5**). The participants estimated relative risk—in relation to a BMI of 38.05—is 2.04 (104%). Whilst this is a cause for concern, this is based only on associative data with a potential for many confounders, but it also puts into perspective the potential risk related to the participants current bodyweight and the lifestyle that caused her poor health status.

**Table 3** – Classification of Weight Status by BMI (WHO, 2000).

| Classification | Obesity class | BMI (kg/m²) |
|---|---|---|
| Underweight | | <18.5 |
| Normal | | 18.5–24.9 |
| Overweight | | 25.0–29.9 |
| Obesity | I | 30.0–34.9 |
| Severe obesity | II | 35.0–39.9 |
| Morbid obesity | III | 40.0–49.9 |
| Severe morbid obesity | III | >50 |

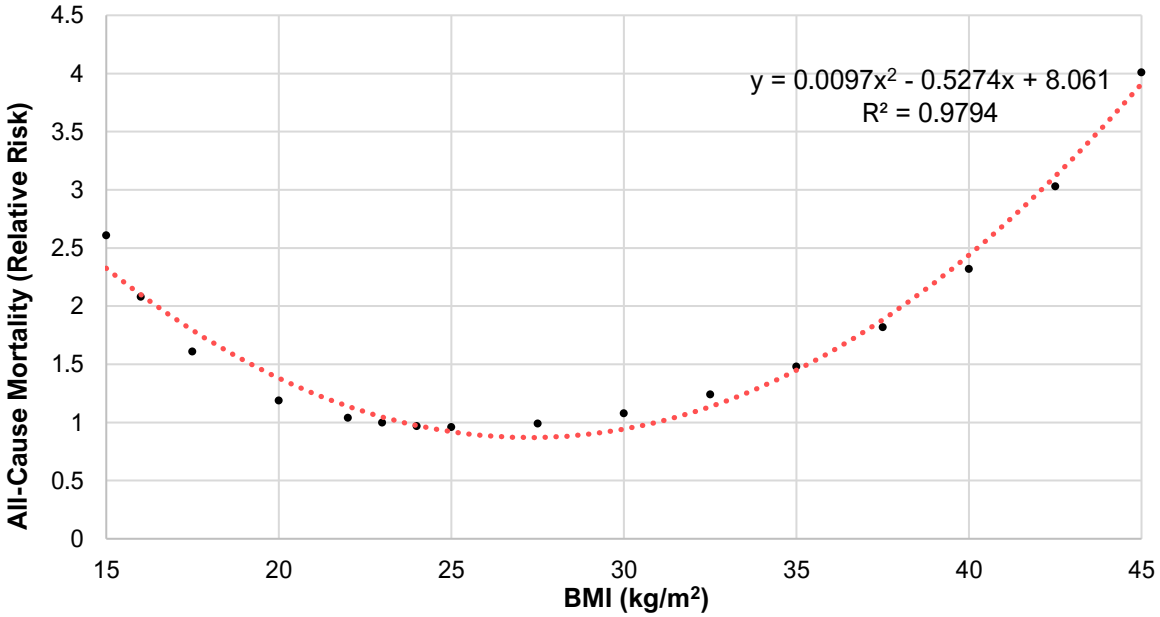


**Figure 5**. Non-linear dose-response analysis of BMI and all-cause morality among current smokers (Aune et al., 2016). A 2nd order polynomial regression was performed, with line equation to calculate the participants estimated relative risk of all-cause morality relating to their BMI.

# Energy Expenditure

The participant provided a description of her daily routine over a 24-hour period with rough estimates of the duration for each activity performed. These activities were categorised into different activity classifications set out by the Food and Agriculture and World Health Organisation (FAO/WHO, 1986). Within each classification, a physical activity ratio (PAR) was used to define the estimated energy expenditure afforded to a specific activity for 1 hour, duration for each activity was converted into hours and was multiplied by the PAR to calculate the energy cost related to the activity and duration (**Table 4**). The participants physical activity level (PAL) was calculated using the formula in **Appendix 1.3**.

**Table 4.** PAR of the participant's sedentary and physical activities over a 24-hour period, with total PAL calculation (FAO/WHO, 1986).

| Time | Task Description | FAO/WHO Activity Classification | Duration (hrs) | Energy cost (PAR) | Duration x energy cost |
|---|---|---|---|---|---|
| 06:45 | Get up and get children Ready for school | Childcare (unspecified) | 1.67 | 2.50 | 4.18 |
| 08:25 | Take the children to school in the car (only a 5-minute drive) | Driving a car/truck | 0.17 | 2.00 | 0.33 |
| 08:45 | Come back home | Driving a car/truck | 0.17 | 2.00 | 0.33 |
| 09:00 | Watch TV | Watching TV | 1.00 | 1.72 | 1.72 |
| 10:00 | Do some cleaning | Sweeping | 1.00 | 2.00 | 2.00 |
| 11:00 | Read book | Reading | 1.50 | 1.25 | 1.88 |
| 12:30 | Lunch | Peeling vegetables | 0.50 | 1.50 | 0.75 |
| | | Eating and drinking | 0.50 | 1.60 | 0.80 |
| 13:30 | Watch a film | Watching TV | 2.00 | 1.72 | 3.44 |
| 15:30 | Pick the children up from school in the car | Driving a car/truck | 0.17 | 2.00 | 0.33 |
| | | Driving a car/truck | 0.17 | 2.00 | 0.33 |
| | | Sitting quietly | 0.67 | 1.20 | 0.80 |
| 16:30 | Get children to choose from the freezer what they want for tea | Sitting quietly | 1.00 | 1.20 | 1.20 |
| 17:30 | Dinner and washing up | Peeling vegetables | 0.50 | 1.50 | 0.75 |
| | | Washing dishes | 0.25 | 1.60 | 0.40 |
| 18:15 | Children's homework | Watching TV | 1.00 | 1.72 | 1.72 |
| 19:15 | Bath children | Bathing child (standing) | 0.75 | 3.50 | 2.63 |
| 20:00 | Put children to bed | Reading | 0.75 | 1.25 | 0.94 |
| 20:45 | Have a bath | Washing hands/face and hair | 0.75 | 2.30 | 1.73 |
| 21:30 | Watch a film with a couple of glass of wine and a cigarette | Watching TV | 1.50 | 1.72 | 2.58 |
| 23:00 | Go to bed | Sleeping | 7.75 | 1.00 | 7.75 |
| | | | | **PAL:** | **1.52** |

The participants PAL was calculated as 1.52, which is classified as sedentary or having a light activity lifestyle (**Table 5**), this accurately describes her physical activity level in relation to the information that was provided by her.

**Table 5**. Classification of lifestyles in relation to the intensity of physical activity level (FAO/WHO, 1986)

| Category | PAL value |
|---|---|
| Sedentary or light activity lifestyle | 1.40-1.69 |
| Active or moderately active lifestyle | 1.70-1.99 |
| Vigorous or vigorously active lifestyle | 2.00-2.40 |

The resting metabolic rate (RMR) was calculated using the equation described in **Appendix 1.2**, which gave the participant an RMR of 1602 kcal/day (66% of total energy expenditure). Given this value, the previously calculated PAL of 1.52, an estimated value of 10% for the thermic effect of food (TEF) and the assumption of no formal exercise, the non-exercise activity thermogenesis (NEAT) was calculated at 590 kcal/day (or 24% of total energy expenditure) (**Table 6**). The estimated energy requirement (ERR) calculation is described in **Appendix 1.4**, which gave the participant an EER of 2435 kcal/day.

**Table 6**. The participants energy expenditure composition

| | PAL | kcal/day | % |
|---|---|---|---|
| **RMR** | 1 | 1602 | 66% |
| **TEF** | 0.152 | 244 | 10% |
| **NEAT** | 0.368 | 590 | 24% |
| **EAT** | 0 | 0 | 0% |
| **Total (EER)** | 1.52 | 2435 | 100% |

# Dietary Analysis

A one-day diet recall was provided by the participant (**Appendix 2**), there was no specific weight or volumes listed, therefore average portion sizes were used where portion size information was missing. A dietary analysis was performed using the information provided by the participant using the software Nutritics (**Appendix 3.1**) and daily recommended values were compared with the UK: SACN 2017 / COMA reference values (Ashwell, 1991; SACN, 2017).

## Energy Balance

The total caloric intake was calculated to determine the participants energy balance status. Based on the information that was given within the diet recall, the participants daily caloric intake was calculated to be 3692 kcal/day (**Table 7**). Carbohydrate provided approximately half of her caloric intake, fat provided approximately a third of her caloric intake and protein and alcohol provided ~10% and ~5% of her caloric intake respectively (**Figure 2**).

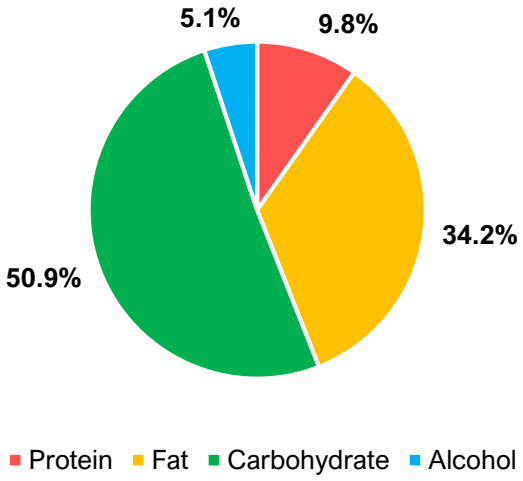


**Figure 2** – The participant's macronutrient ratios

**Table 7**. The participant's energy and macronutrient overview

| | Daily Intake | g/kg/day |
|---|---|---|
| **Energy** | 3682 kcal | - |
| **Protein** | 90 g | 0.95 |
| **Carbohydrate** | 469 g | 4.94 |
| **Fat** | 140 g | 1.47 |
| **Alcohol** | 27 g | - |

When considering the participants daily energy requirements (**Table 6**), a daily intake of 3692 kcal/day would result in a surplus of 1247 kcal/day. This theoretically could result in just under 1kg of weight gain per week, if caloric intake and activity remains constant (disregarding changes in RMR). If this rate of weight gain was extrapolated over 6 months, the participant could see her weight rise to ~120kg, which would give her a BMI of 48 and put her into the morbid obesity class III status. This would also increase her relative risk of all-cause mortality by 3 times compared to her current risk (**Figure 5**).

# Protein

The participants protein intake of 90g a day was above and aligned with the UK government's reference nutrient intake (RNI) of 0.75 g/kg/day or 71.25g for her current bodyweight (**Figure 3**). However, this value is derived from the minimum amount of protein to maintain nitrogen balance and does not acknowledge the potential benefits that may be obtained from a slightly higher protein intake above that level (Lonnie et al., 2018).

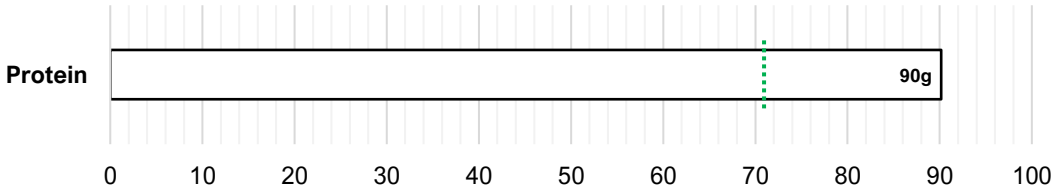


**Figure 3** – The participants daily intake of protein, based on the dietary analysis of the participants food diary (**Appendix 2**)
*Vertical green dotted line represents the reference nutrient intake (RNI).*

Physical activity has been shown to improve protein utilisation and retention (Butterfield and Calloway, 1984), therefore individuals that have low physical activity levels may require increased protein in order to maintain muscle tissue compared to active individuals. Higher protein diets also induce sustained reductions in appetite, ad libitum caloric intake and bodyweight (Bowen et al., 2006; Weigle et al., 2005), which are positive factors to consider, especially if the individual is overweight or obese. To further support this, inadequate dietary protein has been shown to increase hunger and desire to eat (Apolzan et al., 2007), which are negative factors to consider for an individual that is not at a healthy bodyweight.

The protein sources that the participant consumes are relatively poor in nutritional value (**Figure 4**). All of the meat-based sources are either red or processed, whilst this is totally fine in moderation—in conjunction with leaner meats, fish and a diet higher in fruits and vegetables—if these sources comprise her entire meat intake, it could increase the risk of cancer (Alexander et al., 2010; Zhao et al., 2017) and all-cause mortality (Larsson and Orsini, 2014).

| | Cheese | Beef Burger | Ham |
|---|---|---|---|
| |  |  |  |
| **Energy** | 403 kcal | 271 kcal | 145 kcal |
| **Protein** | 24.9g | 26g | 21g |
| **Fat** | 33.1g | 18g | 6g |
| **Saturated Fat** | 21.1g | 7g | 1.8g |
| **Sugar** | 0.5g | 0g | 0g |
| **Salt** | 1.55g | 0.19g | 3g |

**Figure 4** – The main protein sources consumed by the participant with UK nutrition labelling information per 100g. Red shading represents the nutrient is high or less healthy. Green shading represents the nutrient is low or healthier. Amber shading represents the nutrient is medium. Guidelines and colour coding are based off the NHS Eatwell Guide (NHS, 2018). Food nutrient values were taken from the Nutritics database (**Appendix 3.1**)

# Fat

The participants total fat intake of 140g a day was nearly double the recommended value based off the estimated UK energy requirement for females aged 19+ years (35% of 2000 kcal). Monounsaturated and total polyunsaturated fats were sufficient and fell within the recommended levels, however saturated fat was more than double the recommended upper limit based off the estimated UK energy requirement for females aged 19+ years (11% of 2000 kcal) (**Figure 5**). This level of saturated fat intake is a cause of concern due to the increased risk of cardiovascular disease (Clifton and Keogh, 2017; Nettleton et al., 2017), due to its effect on raising low-density lipoprotein (LDL) cholesterol and lowering high-density lipoprotein (HDL) cholesterol (Siri-Tarino et al., 2010; Vincent et al., 2019). A meta-analysis found oxidised LDL to be directly linked to atherosclerotic cardiovascular events (Gao et al., 2017) and in a meta regression and meta-analysis, cardiovascular mortality risk was reduced after LDL-C was lowered (Navarese et al., 2018).

High fat, high-saturated fat diets have also been shown to influence the progression of type 2 diabetes, mainly through increasing insulin resistance (Hernández et al., n.d.; Koska et al., 2016; Riccardi et al., 2004; von Frankenberg et al., 2017), which is said to be mediated by the activation of a cascade that leads to defects in insulin signalling and glucose transport (Delarue and Magnan, 2007).

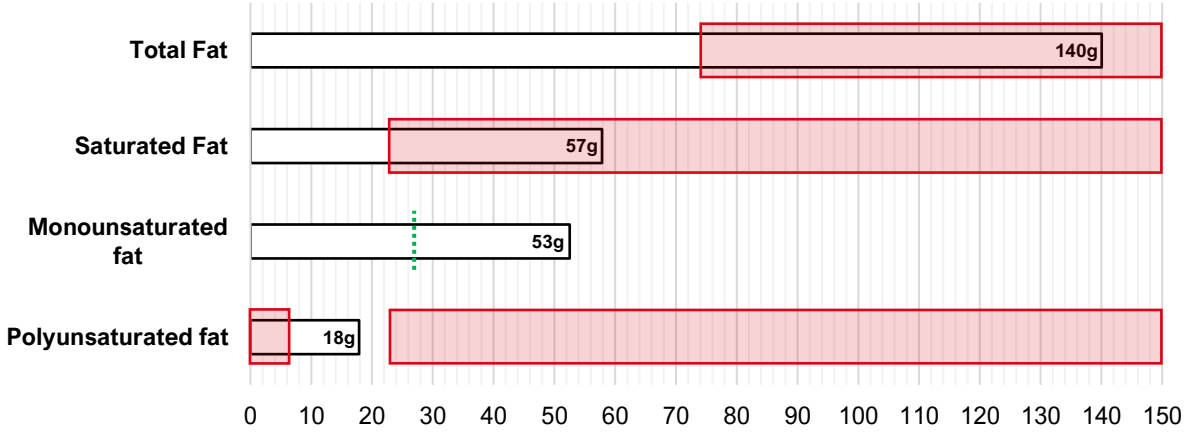


**Figure 5** – The participants daily intake of total, saturated, monounsaturated and polyunsaturated fat, based on the dietary analysis of the participants food diary (**Appendix 2**)

*Red shaded bars to the left represent the lower limit of each nutrient.*
*Red shaded bars to the right represent the upper limit of each nutrient.*
*Vertical green dotted line represents the reference nutrient intake (RNI).*

Intakes of omega-3 and omega-6 polyunsaturated fats were not below the recommended lower limit for the participants intake (**Figure 6**), although the ratio of omega-6 to omega-3 (6:1) could be slightly high and an area for improvement. Keeping a low ratio of omega-6/omega-3 has been shown to be important for reducing the risk of many chronic diseases such as cardiovascular disease, cancer and inflammatory and auto immune diseases (DiNicolantonio and O'Keefe, 2018; Simopoulos, 2002). An increase in the ratio of omega-6/omega-3 fatty acids have been implicated in increasing the risk for obesity (Simopoulos, 2016), metabolic syndrome (Jang and Park, 2020) and depression (Kiecolt-Glaser et al., 2007).

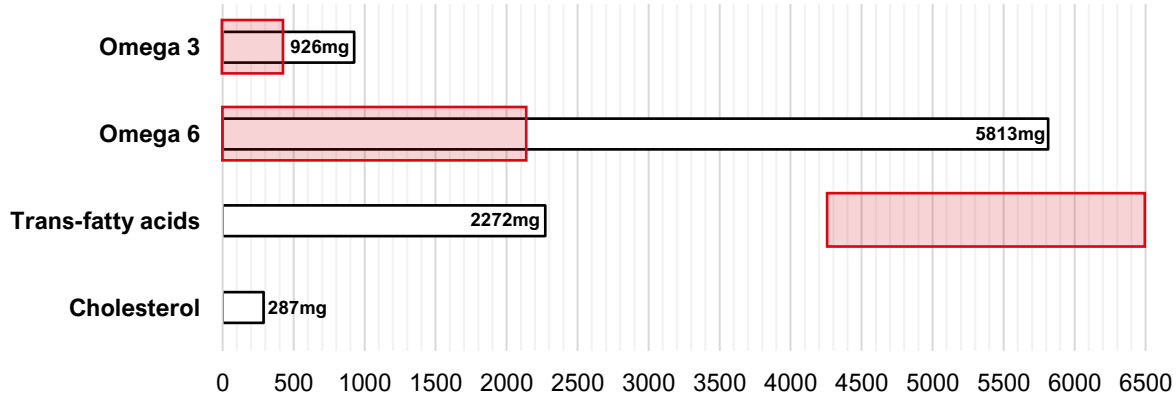


**Figure 6** – The participants daily intake of omega-3, omega-6, trans-fatty acids and cholesterol based on the dietary analysis of the participants food diary (**Appendix 2**)

*Red shaded bars to the left represent the lower limit of each nutrient.*
*Red shaded bars to the right represent the upper limit of each nutrient.*

The main fat sources that the participant consumes are of low nutritional value, they also explain her very high total and saturated fat intake, along with her lack of omega-3 polyunsaturated fats (**Figure 7**).


| | Cheese | Butter |
|---|---|---|
| **Energy** | 403 kcal | 717 kcal |
| **Protein** | 24.9g | 09g |
| **Fat** | 33.1g | 81.1g |
| **Saturated Fat** | 21.1g | 51.4g |
| **Sugar** | 0.5g | 0g |
| **Salt** | 1.55g | 1.44g |

**Figure 7** – The main sources of fat consumed by the participant with UK nutrition labelling information per 100g. Red shading represents the nutrient is high or less healthy. Green shading represents the nutrient is low or healthier. Amber shading represents the nutrient is medium Guidelines and colour coding are based off the NHS Eatwell Guide (NHS, 2018). Food nutrient values were taken from the Nutritics database (**Appendix 3.1**)

## Carbohydrate

The total intake of carbohydrate is the highest macronutrient out of all the macronutrients, making up 50% of her total caloric intake. Whilst this aligns with the recommended level in terms of percentage value, the extremely high caloric intake of the participant results in a daily carbohydrate intake that is close to double the recommended level based off the estimated UK energy requirement for females aged 19+ years (50% of 2000 kcal) (**Figure 8**).

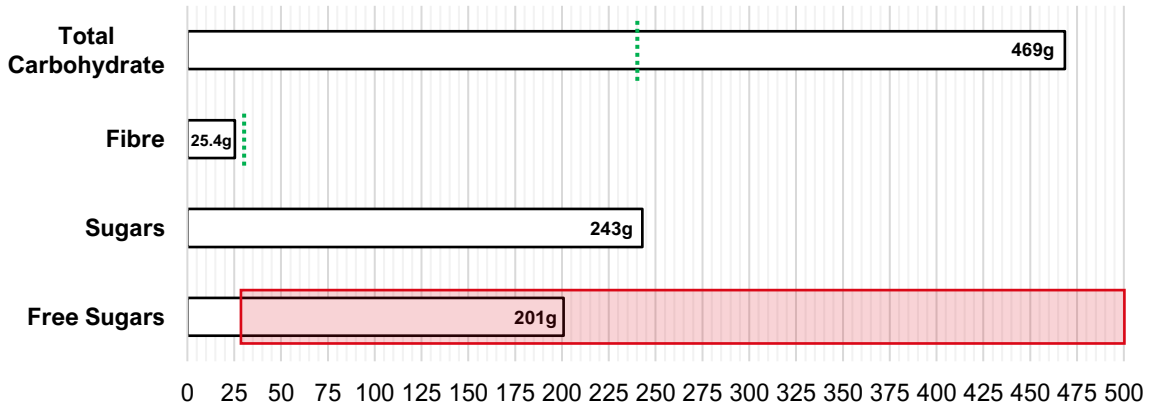


**Figure 8** – The participants daily intake of total carbohydrate, fibre, sugars and free sugars, based on the dietary analysis of the participants food diary (**Appendix 2**)
*Red shaded bars to the right represent the upper limit of each nutrient.*
*Vertical green dotted line represents the reference nutrient intake (RNI).*

## Fibre

The participants intake of fibre was below the recommended level by ~5g (**Figure 8**), this is not a large amount to be under, but for the amount of food that is being consumed on a daily basis, this is a cause of concern and a reflection on poor food choices (**Figure 9**). Dietary fibre is a vital component to human health and is known to be protective against many diseases (Otles and Ozgoz, 2014). Most known for its association with decreasing the risk of atherosclerosis and cardiovascular disease (Lairon et al., 2005; McRae, 2017; Soliman, 2019), but also specifically in the protective effects that dietary fibre has against colorectal cancer (Ma et al., 2018; Murphy et al., 2012) and breast cancer (Chen et al., 2016).

Fibre has also been shown to impact insulin resistance and prevent the progression of type 2 diabetes (Kuijsten, 2015; McRae, 2018; Tabatabai and Li, 2000). Large prospective cohort studies consistently show associations of high dietary fibre intake (> 25 g/day in women and > 38g/day in men) with a 20 – 30% reduction in the risk of developing type 2 diabetes (Weickert and Pfeiffer, 2018). Dietary fibre has been shown to promote weight loss and dietary adherence with consuming a calorie-restricted diet, independent of macronutrient and caloric intake (Miketinas et al., 2019), therefore highlighting its importance in the management of obesity.

## Sugar

Sugar intake was another area of concern that should be addressed to improve the participants diet and health due to level of intake. Data on the association between added sugar intake and mortality indicates that high sugar consumption (> 20% of total energy) is associated with an increased mortality risk (Ramne et al., 2019). The participant currently consumes ~26% of total energy from sugar (or 243 g/day) and ~21% of total energy from free sugars (or 201g/day) (**Figure 8**), and the recommended upper limit for free sugars is 24 g/day.

Higher sugar intake, in the context of excess energy has been shown to increase insulin resistance and obesity, and exacerbate the development of type 2 diabetes (Macdonald, 2016). The consumption of sugar-sweetened beverages has consistently been shown to be associated with all-cause mortality over multiple cohorts and countries (Anderson et al., 2020; Malik et al., 2019; Mullee et al., 2019).

When free sugars or fructose-containing sugars are within normal ranges, the risk of obesity, cardiometabolic disease and diabetes is insignificant (Janket et al., 2003; Rippe and Angelopoulos, 2016). Free sugars can only lead to weight gain or increase disease risk from the excess calories that may be inherent in their consumption (Khan and Sievenpiper, 2016).

The main carbohydrate sources that the participant consumes are of very low nutritional value, they also explain her very high sugar and free sugar intake, along with her lack of fibre in respect to her total caloric intake (**Figure 9**).

| | Sugar | Jam | Chocolate Biscuits | Fairy Cake | Crisps | Doughnut | Coke | Chocolate Cake | Chips | Popcorn |
|---|---|---|---|---|---|---|---|---|---|---|
| **Energy** | 378 kcal | 278 kcal | 496 kcal | 384 kcal | 520 kcal | 328 kcal | 43kcal | 444 kcal | 201 kcal | 444 kcal |
| **Protein** | 0g | 0.4g | 6.7g | 5.1g | 6.3g | 5.9g | 0g | 7.9g | 3.3g | 6.5g |
| **Fat** | 0g | 0.1g | 23.6g | 13g | 31g | 13g | 0g | 24g | 6.7g | 16g |
| **Saturated Fat** | 0g | 0g | 12.4g | 7.2g | 2.5g | 5g | 0g | 8.3g | 0.8g | 1.2g |
| **Sugar** | 100g | 48.5g | 25.8g | 44g | 3.3g | 20g | 11g | 27g | 1.5g | 28g |
| **Salt** | 0g | 0.08g | 0.94g | 0.82g | 1.2g | 1g | 0.01g | 0.88g | 0g | 1.3g |
| **Fibre** | 0g | 0 | 2.9g | 4.18g | 4.85g | 1.94g | 0g | 1.57g | 3.76g | 9.9g |

**Figure 9** – The main sources of carbohydrate consumed by the participant with UK nutrition labelling information per 100g. Red shading represents the nutrient is high or less healthy. Green shading represents the nutrient is low or healthier. Amber shading represents the nutrient is medium Guidelines and colour coding are based off the NHS Eatwell Guide (NHS, 2018). Food nutrient values were taken from the Nutritics database (**Appendix 3.1**).

## Minerals

The participants mineral intake along with the associated RNI's can be seen in **Figure 10**. An area for concern, among her overall mineral intake, was the amount of sodium that was consumed daily. Her intake was 3314 mg/day, which is ~913 mg above the recommended upper limit for sodium, although this is more a product of her overall caloric consumption than consuming foods that are higher in salt. Data shows a clear link between excessive sodium intake and increased all-cause mortality risk (Cook et al., 2016), especially in the pathogenesis of hypertension (Grillo et al., 2019; Rust and Ekmekcioglu, 2017) and cardiovascular disease (Cappuccio, 2013; Morrison and Ness, 2011). Other reviewers have explored U-shaped associations with sodium intake and mortality, concluding that both low and high intakes of sodium contribute to increasing mortality (Graudal et al., 2014).

A mineral that was below the recommended lower limit was selenium, the participant does not include any good sources of selenium in their diet (e.g. seafood, eggs or brazil nuts), therefore its no surprise that they were deficient. Selenium is an essential trace mineral, its vital to proper thyroid hormone production and immune system functioning (Rayman, 2000).

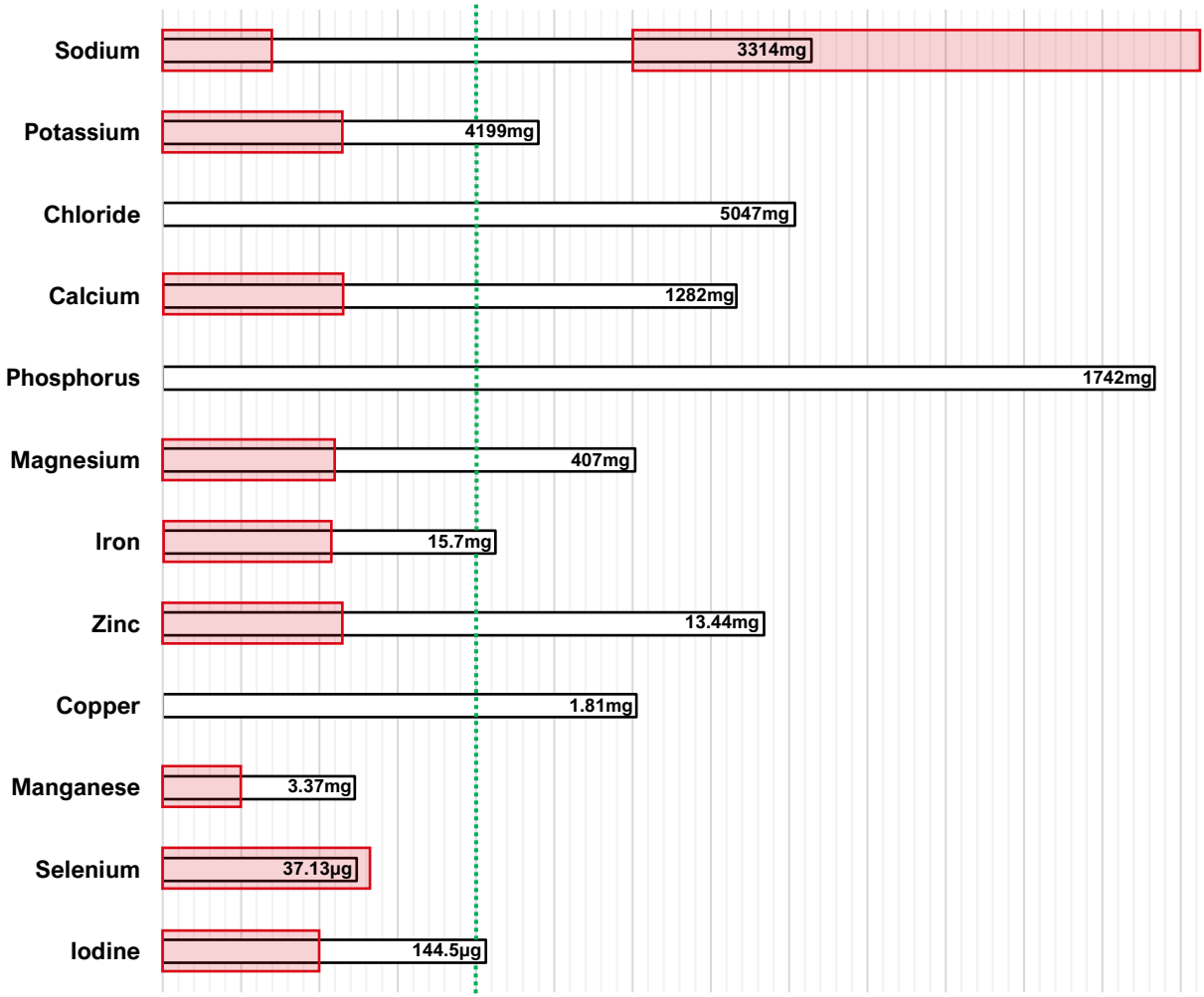


**Figure 10** – The participants mineral intake based dietary analysis of the participants food diary (**Appendix 2**). Values are displayed as the percentage of nutrient compared to the RNI.
*Red shaded bars to the left represent the lower limit of each nutrient.*
*Red shaded bars to the right represent the upper limit of each nutrient.*
*Vertical green dotted line represents the reference nutrient intake (RNI).*

## Vitamins

The participants vitamin intake along with the associated RNI's can be seen in **Figure 11**. There were no vitamins that were below the recommended lower limits, although some did not meet the recommended RNI and her overall vitamin intake would worsen if she consumed the same types of food at a more appropriate caloric intake in accordance with her energy needs.

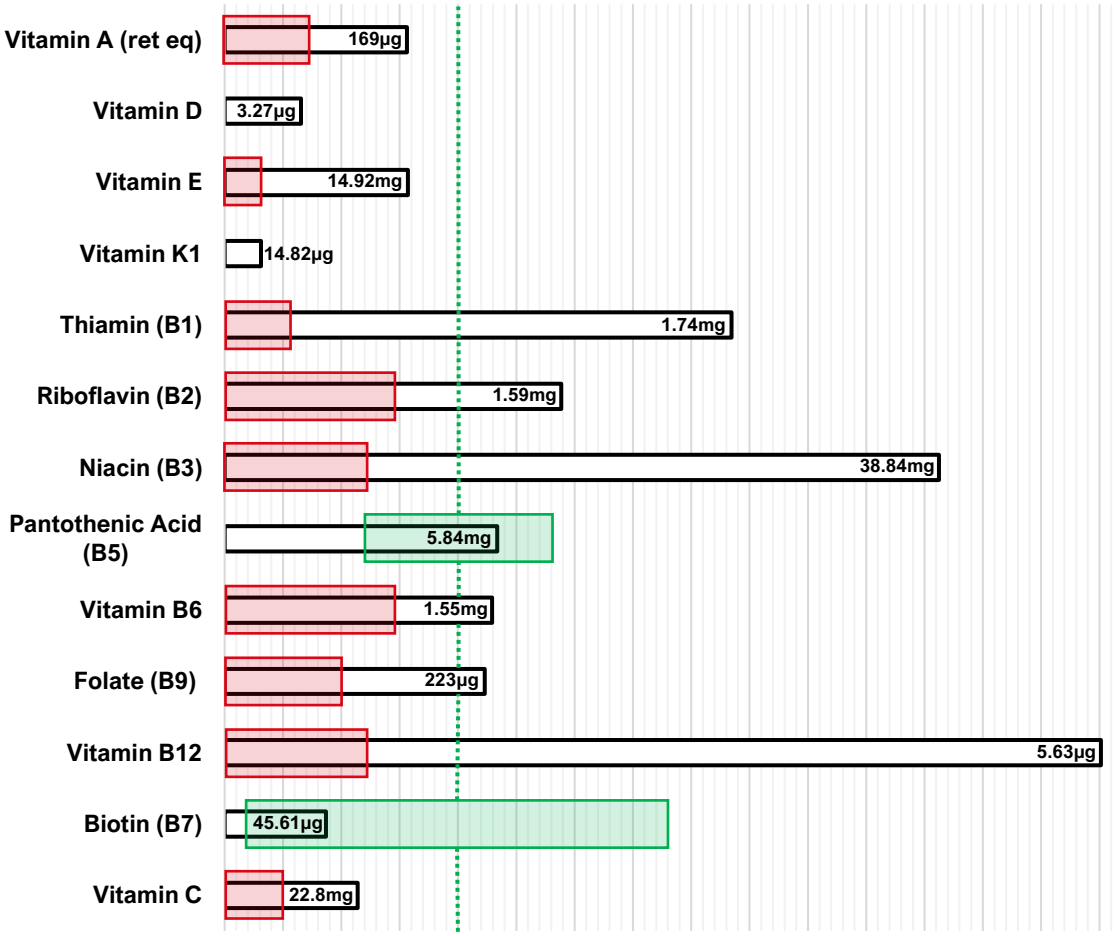


**Figure 11** – The participants mineral intake based dietary analysis of the participants food diary (**Appendix 2**). Values are displayed as the percentage of nutrient compared to the RNI.

*Red shaded bars to the left represent the lower limit of each nutrient.*
*Red shaded bars to the right represent the upper limit of each nutrient.*
*Vertical green dotted line represents the reference nutrient intake (RNI).*
*Green shaded bars represent recommended ranges for the nutrient.*

Vitamin D could be an area for improvement considering it was more than half the RNI and because there is substantial evidence to support the health benefits of ensuring optimal intake is achieved. A meta-analysis that looked at mortality according to serum 25-hydroxyvitamin D (25(OH)D) found that there is a significant reduction in all-cause mortality with serum concentrations greater than 30 ng/mL (75 nmol/L) (Garland et al., 2014).

Another meta-analysis investigated 108 randomised controlled trials on vitamin D supplementation and vitamin D status. They found that to achieve 25(OH)D concentrations of 50 nmol/L or more, 97.5% of overweight and obese people would have to consume 4450 IU and 7248 IU respectively. Although, 2.5% of overweight and obese people would end up with concentrations above 200 and 214 nmol/L respectively taking those dosages (Veugelers et al., 2015). The reason for this increased requirement is due to the impaired bioavailability of vitamin D that occurs in individuals who are overweight or obese that hold excess adipose tissue (Migliaccio et al., 2019; Wortsman et al., 2000).

## Caffeine

That participants caffeine consumption consisted of 7 cups of coffee over the course of the day, this was calculated as 398 mg/day (**Figure 12**), some data has shown consumption at these levels to have protective effects against hypertension in females (Geleijnse, 2008). Other studies found moderate levels of caffeine consumption (2 - 4 cups of coffee a day) to be considered safe within healthy populations (Nieber, 2017; Poole et al., 2017). However, there may be potential harm to some vulnerable groups including people with cardiovascular dysfunction, sleep impairment (Temple et al., 2017) or pregnant women (Butt and Sultan, 2011). A recent meta-analysis of 40 studies found inverse associations between coffee consumption and mortality from all-causes, cardiovascular disease and cancers (Kim et al., 2019). A small reduction to overall caffeine intake may be advisable for the participant, especially to the consumption of caffeine in the PM, as this may impact on her sleep quality (Sanchez et al., 2013; Watson et al., 2016).

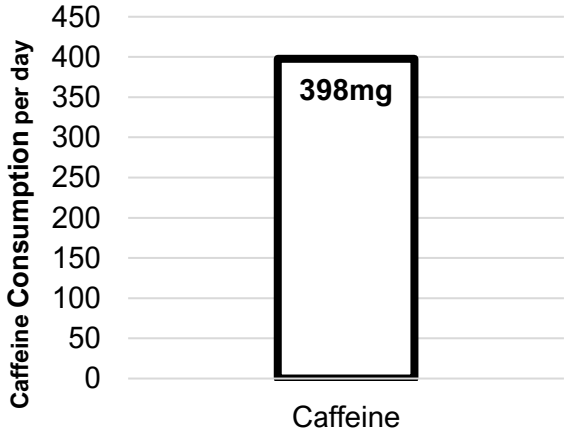


**Figure 12** - The participants daily caffeine consumption, based on dietary analysis of the participants food diary (**Appendix 2**).

## Alcohol

The participants alcohol consumption consisted of two small glasses of red wine in a typical day. If this level of consumption occurred daily, this would equate to ~23 units per week (**Figure 13**). The UK guidelines for alcohol consumption states that men and women who drink regularly, are safest to not drink more than 14 units per week (Rosenberg et al., 2018), therefore the participant could be potentially exceeding that recommendation by 60%. Many studies have found that all-cause mortality risk substantially increases as units of alcohol per week exceeds 8 units for women and 5 units for men (White et al., 2002). A reduction in alcohol consumption to below 14 units a week will improve overall health and reduce future disease risk.

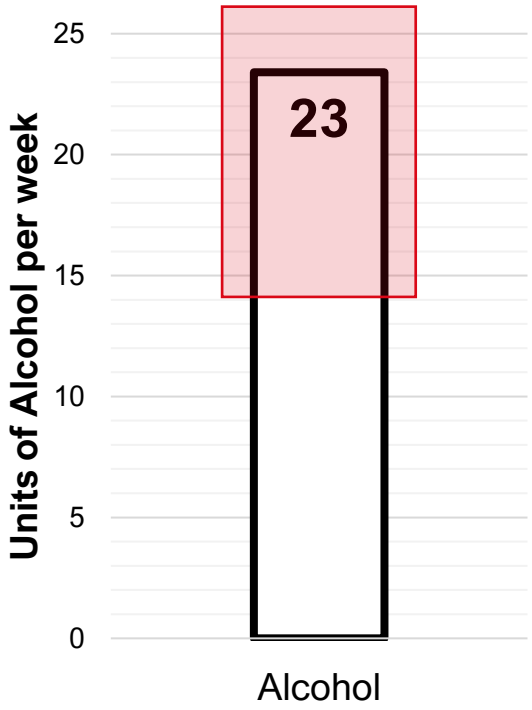


**Figure 13** - The participants weekly alcohol consumption, based on dietary analysis of the participants food diary (**Appendix 2**).
*Red shaded bars to the top represent the upper limit of alcohol units per week (14)*

# Recommendations & Summary

If the participant continues her current diet and lifestyle, the potential for further increasing the risk of ill-health and disease later in life becomes very likely. The most important factor that need be addressed is the participants energy balance. Therefore, a substantial reduction in caloric intake, coupled with an incorporation of increased activity level should be the first initial step to see improvements in health and wellbeing. Reducing dietary fat, simple sugars and sodium will contribute a great deal to the participants ability to regulate their calorie intake, this is due to the high palatability of these nutrients (often in combination), thus making them prone for overconsumption (Fazzino et al., 2019). They should try to limit the amount of junk food, confectionary and sugar sweetened beverages they consume as this will substantially reduce dietary fat, simple sugars and sodium, but also that ultra-processed diets (that contain these food types) have been shown to increase ad libitum intake by ~500 kcal/day compared with unprocessed diets (Hall et al., 2019). Therefore, a switch to unprocessed/whole foods—that provide a higher nutrient density, more satiation, less inflammation and a reduce caloric density will allow the participant to sustain a lower calorie intake whilst improving overall micronutrient profile.

The participant may benefit from a slightly higher protein intake from food sources that are lower in saturated fat and higher in essential fatty acids. A switch to lean meats, eggs and oily fish—as the foundation of her protein intake—would allow for more complete proteins with less calories, an improved micronutrient profile and adequate intake of omega 3 fatty acids. An increase in more complex and fibre bound sugars such as whole grains, fruits and vegetables should be adopted by the participant. This will help provide adequate fibre intake and further improve the participants micronutrient profile, contributing to reducing the risk of multiple comorbidities and aiding in weight management over the course of the future.

An example of a nutritional plan that would fulfil these improvements can be viewed in **Supplementary Material 1**.

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# Appendices

## Appendix 1: Equations & Calculations

### 1.1: Body Mass Index

Body mass index was calculated using the body mass index equation popularised adopted by Ancel Keys and co (Keys et al., 1972).

$$Bodyweight\ in\ kilograms\ /\ (Height\ in\ metres^2)$$

### 1.2: Resting Metabolic Rate

RMR was calculated using the female version of the Mifflin St Jeor resting energy expenditure equation (Mifflin et al., 1990).

$$(10\ *\ Bodyweight\ in\ kilograms) + (6.25\ *\ Height\ in\ centimetres\ ) - (5\ *\ Age) - 161$$

### 1.3: Physical Activity Level

Physical Activity Level was calculated using the Food and Agriculture Organization and World Health Organisation activity classification with Physical Activity Ratios (**Table 2**) and the following formula (FAO/WHO, 1986):

$$\frac{[SUM\ of\ all\ activities: (Duration *\ PAR)]}{24} = PAL$$

### 1.4: Estimated Energy Requirement

Estimated energy requirement was calculated by taking the participant's resting metabolic rate (**Appendix 1.2**) and multiplying by their estimated physical activity level (**Appendix 1.3**)

$$RMR\ *\ PAL$$

# Appendix 2: Dietary Recall (1 Day)

A food diary representing the participants typical daily intake of food and drink

| Time | Food intake | Other |
|---|---|---|
| 07:00 | 2 cups of coffee (with two teaspoons of sugar and whole milk) | 2 cigarettes |
| | 2 slices white toast with butter and Jam | |
| 09:00 | Cup of coffee (with two teaspoons of sugar and whole milk) and two chocolate digestives | 1 cigarette |
| 10:30 | Mid - morning snack (fairy cake) | 1 cigarette |
| | Cup of coffee (with two teaspoons of sugar and whole milk) and two chocolate digestives | |
| 12:30 | Toasted cheese and ham sandwich | 2 cigarettes |
| | Bag of crisps | |
| | Jam Doughnut | |
| | Can of coke | |
| 15:30 | Cup of coffee (with two teaspoons of sugar) | 2 cigarettes |
| | teaspoons of sugar) | |
| 17:00 | Burger in a bun with cheese | 3 cigarettes |
| | Potato Chips | |
| | Baked Beans | |
| | Chocolate pudding with ice cream | |
| | Small glass of red wine | |
| 20:00 | Cup of coffee (with two teaspoons of sugar and whole milk) | |
| 21:30 | Small glass of red wine | 2 cigarettes |
| | A bag of popcorn | |
| 23:00 | Cup of coffee (with two teaspoons of sugar and whole milk) | 1 cigarette |

# Appendix 3: Software

## 3.1: Dietary Analysis Software

Nutritics was used to analyse the participants diet via their diet recall and their PAL was estimated using the in-built calculator (Nutritics, 2019)

## 3.2: Reference Manager Software

Zotero was used to manage the references in this report (Zotero: The Next Generation Research Tool, 2006)

# Supplementary Material 1 - Nutrition Plan & Dietary Analysis

A nutrition plan to fulfil the proposed recommendations and improvements to the participants health. Also included is a dietary analysis of the new nutrition plan. Constructed using Nutritics dietary analysis application (**Appendix 3.1**).