# Sex differences in Obesity and Responses to Obesity treatment

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**Statement of originality**

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……..

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Rebecca Williams reports no conflicts of interest.

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**2. RL Williams**, LG Wood, CE Collins and R Callister. Comparison of fruit and vegetable intakes during weight loss in males and females. *European Journal of Clinical Nutrition* (2016), 70, 28–34. doi:10.1038/ejcn.2015.123

**3. Williams, Rebecca L**; Wood, Lisa G; Collins, Clare E; Morgan, Philip J; Callister, Robin. Energy homeostasis and appetite regulating hormones as predictors of weight loss in men and women. *Appetite*. 2016 June; 101:1-7. doi:10.1016/j.appet.2016.02.153

**Publications and presentations conducted aside from this thesis**

**1.** Collins CE, Neve MJ, Morgan PJ, Fletcher K, **Williams R**, Young M, Callister R. Effectiveness of interventions with a dietary component on weight loss maintenance: A systematic review. The JBI Database of Systematic Reviews and Implementation Reports, 2013; **11**(8) 317 – 414.

**2.** Jensen ME, Wood LG, **Williams R**, Collins CE. Associations between Sleep Architecture, Dietary Intake and Physical Activity in Children: A Systematic Review. 2013. JBI Library of Systematic Reviews (accepted 13th February 2013). SR511.

**3.** Plotnikoff, R., Collins, C., **Williams, R.**, Germov, J., & Callister, R. (2014). Effectiveness of interventions targeting health behaviors in University and College staff: A systematic review. *American Journal of Health Promotion.* doi: 10.4278/ajhp.130619-LIT-313

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**5.** Tracy L. Burrows, **Rebecca Williams**, Megan Rollo, Lisa Wood, Manohar L. Garg, Megan Jensen, Clare E. Collins. Plasma carotenoid levels as biomarkers of dietary carotenoid consumption: A systematic review of the validation studies. Journal of Nutrition & Intermediary Metabolism 2 (2015) 15-64.

**6.** Jacklyn Jackson, **Rebecca Williams**, Mark McEvoy, Lesley MacDonald-Wicks, Amanda Patterson. Is higher consumption of animal flesh foods associated with better iron status among adults in developed countries: A systematic review. *Nutrients,* 2016 ***8***(2), 89; doi:10.3390/nu8020089

**Chapters with intent to submit to peer-reviewed journals**

**1.** Chapter 4: Changes to dietary intake of fat and energy-dense, nutrient-poor foods in males and females during weight loss. **RL Williams**, LG Wood, CE Collins and R Callister.

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**1. Williams R**, Brown L. Hydration Status and Practices of Junior Rugby Union Players. Abstract; International Congress of Dietetics, Sydney, 2012.

**2.** Robin Callister, **Rebecca Williams**, Lisa Wood, Philip Morgan, Clare Collins. Energy and appetite regulating hormones: Sex and weight category differences prior to weight loss. Abstract; ANZOS, Melbourne, 2013.

**3. Rebecca Williams**, Lisa Wood, Clare Collins, Robin Callister. Energy and appetite regulating hormones: Do they differ between males and females? Abstract; Nutrition Society of Australia, Brisbane, 2013.

**4. Rebecca Williams**, Lisa Wood, Clare Collins, Robin Callister. Effectiveness of weight loss interventions – is there a difference between males and females: A Systematic review. Abstract; ANZOS, Sydney, 2014

**5.** Tracy L. Burrows, **Rebecca Williams**, Megan Rollo, Lisa Wood, Manohar L. Garg, Megan Jensen, Clare E. Collins. Plasma carotenoid levels as biomarkers of dietary carotenoid consumption: A systematic review of the validation studies. Abstract; Nutrition Society of Australia, Tasmania 2014

**6. RL Williams**, LG Wood, CE Collins and R Callister. Comparison of fruit and vegetable intakes during weight loss in males and females. Abstract; Nutrition Society of Australia, Wellington, NZ, 2015

**7.** Jacklyn Jackson, **Rebecca Williams**, Mark McEvoy, Lesley MacDonald-Wicks, Amanda Patterson. Is higher consumption of animal flesh foods associated with better iron status among adults in developed countries: A systematic review. Abstract; Nutrition Society of Australia, Wellington, NZ, 2015

**Glossary of common abbreviations**

| | |
|---|---|
| Adipo1 | Adiponectin receptor 1 |
| Adipo2 | Adiponectin receptor 2 |
| AES | Australian eating survey |
| AGHE | Australian Guide to Healthy Eating |
| AgRP | Agouti-related peptide |
| AMDR | Acceptable Macronutrient Distribution Range |
| BMI | Body mass index |
| BMR | Basal metabolic rate |
| CCK | Cholecystokinin |
| cm | Centimetre |
| CNS | Central nervous system |
| CONSORT | Consolidated Standards of Reporting Trials |
| CRP | C-Reactive protein |
| CVD | Cardiovascular disease |
| DASH | Dietary approaches to stop hypertension |
| EDTA | Ethylene-diamine-tetra-acetic acid |
| FM | Fat mass |
| GHS-R | Growth hormone secretagogue receptor |
| GLP-1 | Glucagon-like peptide 1 |
| GLP-2 | Glucagon-like peptide 2 |
| IL-6 | Interleukin-6 |
| HDL | High-density lipoprotein |
| HMW | High-molecular weight |
| HP | High protein |

| | |
|---|---|
| JAK-STAT3 | Janus kinase/signal transducers and activators of transcription-3 |
| Kg | Kilogram |
| kJ | Kilojoule |
| lb | Pound |
| LBM | Lean body mass |
| LDL | Low-density lipoprotein |
| LepR-β | Leptin receptor beta |
| LMW | Low molecular weight |
| LP | Low protein |
| NRV | Nutrient reference value |
| OECD | Organisation for economic cooperation and development |
| PA | Physical activity |
| PI3K | Phosphoinositide 3-kinase |
| PPAR | Peroxisome proliferator-activated receptors |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| PYY | Peptide YY |
| RCT | Randomised controlled trial |
| SP | Standard protein |
| TE | Total energy |
| TG | Triglycerides |
| TNF-α | Tumor necrosis factor-alpha |

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# SYNOPSIS

The prevalence of obesity and obesity related chronic diseases are still a major health concern and poor dietary intake is a large contributor. Sex differences may predispose an individual to becoming overweight or obese or may determine how individuals respond to lifestyle interventions. Research is needed that increases our understanding of how sex modifies the development and treatment of overweight and obesity. Therefore, intervention impacts need to be tested, and their effectiveness established, separately for males and females. This thesis aims to investigate sex differences in obesity, in particular, differences in weight loss success, dietary approaches to weight loss and physiological factors associated with weight loss and dietary intake, namely the appetite and energy homeostasis regulating hormones leptin, ghrelin and adiponectin.

A systematic review was conducted to determine whether the effectiveness of weight loss interventions is the same for males and females and if not, which interventions are better suited to each of the sexes. Overall, males lost more absolute weight than females, however females were still successful. Few differences in weight loss were found when differences in baseline weight were accounted for. Analysis of effect sizes found small differences in weight loss favouring men for both diet and diet plus exercise interventions. There is little evidence from this review to indicate that men and women should adopt different weight loss strategies. Current evidence supports moderate energy restriction in combination with exercise for weight loss in both men and women.

The next study investigated sex differences in self-selected dietary intakes of fruits and vegetables, fat, and energy-dense, nutrient-poor foods during a weight loss intervention. Dietary intake was assessed using the Australian Eating Survey and fasting blood was collected to assess plasma carotenoids and fatty acids. There was little change in fruit or vegetable intakes during weight loss, although men tended to increase fruit intakes. Males and females significantly reduced their intakes of fat (g) and energy-dense, nutrient-poor foods during weight loss, however their intakes of energy-dense,

nutrient-poor foods were still 35% of total energy intake during weight loss. Males had better correlations between fruit and vegetable intakes and plasma carotenoid concentrations than females. There were few correlations between dietary fatty acids intake and RBC membrane fatty acids. Fruit and vegetable and fat intakes during weight loss appear to predict weight loss for males but not females.

The next study investigated the association between baseline energy homeostasis and appetite regulating hormones and weight loss success in males and females. Females had significantly higher baseline concentrations of leptin, adiponectin and unacylated ghrelin as well as ratios of leptin:adiponectin and leptin:ghrelin. The ratio of acylated:unacylated ghrelin was significantly higher in males. In males and females, a higher baseline concentration of unacylated ghrelin predicted greater weight loss at six months. Additionally in females, higher baseline total ghrelin predicted greater weight loss and a higher ratio of leptin:ghrelin predicted weight gain at six months. Further investigation is required into what combinations and concentrations of these hormones are optimal for weight loss success.

Investigating whether particular nutrients or dietary patterns can alter hormone concentrations may reveal an important link that could help in the development of more effective weight loss strategies. Concentrations of leptin, adiponectin and ghrelin were measured at baseline of a weight loss intervention and habitual dietary intake was assessed in the six months prior. Associations between usual dietary intake and hormone concentrations were more common in females than males. It appears that a diet higher in fruits and vegetables and lower in energy-dense, nutrient-poor foods may have a more favourable effect on appetite in females, however further research is required that investigates the influence of usual dietary intake on hormone concentrations in both males and females, particularly in relation to weight change.

This thesis has identified a number of key areas that should be considered in future studies in order to progress this area of research. Further research needs to be conducted under real world conditions to elucidate which dietary strategies are preferred and adopted by males and females attempting weight loss and whether

these strategies are in fact effective for weight loss and maintenance. To determine if there is a true difference in weight loss success between males and females, interventions should report weight loss as a percentage of baseline weight. Any future research investigating the relationship between dietary intake and appetite and energy homeostasis regulating hormones needs to control for sex differences in these hormones, and also needs to identify mis-reporters and potentially exclude them from the analysis. Identification of the dietary preferences of males and females during weight loss and any lifestyle interventions that can favourably alter hormone concentrations for both males and females has the potential to change the way current weight loss advice is provided.