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MEAL REPLACEMENT: A WAY FORWARD IN THE MANAGEMENT OF OBESITY.

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Introduction

Obesity is described as a global pandemic & is the most widespread metabolic disorders in several countries. [Marie et al., 2014, Constantine et al., 2008] According to WHO, overweight and obesity are defined as abnormal or excessive fat (adipose tissue) accumulation which occurs as a result of an energy imbalance either due to increased energy intake or decreased energy output or a combination of both [WHO, 2015]. Since obesity is a complex & multi-factorial disorder, a single causative factor cannot be pointed out. Obesity is a consequence of complex interactions between genetic, social, environmental and behavioural factors [Constantine et al., 2008, Seagle et al., 2009]. Obesity is a serious chronic disease and is a pre-disposition to complicating conditions like cardiovascular diseases, type 2 diabetes mellitus, certain cancers, asthma, sleep apnoea and osteoarthritis. This may be attributed to the inflammation and oxidative stress created by excessive visceral adipose tissue. Besides these health risks obese individuals often bear social discrimination and stigma and thus may experience impaired psychological functioning. Therefore, obesity impairs the quality of life of an individual; it reduces life span and increases overall mortality and morbidity [Sadaf et al., 2014, Lisa et al., 2010].

Assessment of obesity :

Assessment of obesity is a pre-requisite for its treatment. Several anthropometric measures are used to predict and classify obesity. Body Mass Index (BMI) is the most widely used predictor for obesity. Table 1 shows the cut-off criteria used to identify obesity based on BMI. Waist circumference is strongly correlated to visceral adiposity. For South Asians the cut-off for waist circumference is >90cm for men and >80cm for women. Besides these waist-to-hip ratio and body composition are also used to identify obesity. A higher body fat is strongly associated with increased risk of metabolic syndrome, thus while treating obesity the aim should be to lose body fat and maintain fat free mass/lean body mass. [WHO. 2008, A Misra et al., 2009].

Prevalence of obesity:

Owing to the rising urbanization and industrialization, worldwide obesity has nearly doubled since 1980. In 1980; 857 million individuals were overweight and obese which increased to 1.9 billion by

2014. Of this, 600 million were obese. WHO global estimates from 2014 revealed that overall 39% of world's adult population were overweight and 13% were obese. Overweight and obesity are no longer a problem of high-income countries but are also on a rise in low and middle income countries [WHO, 2015]. Results from a systematic analysis of the global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013 are shown in Table 2. India and China together accounted for 15% of world's adult obese population with 30 million and 46 million obese individuals respectively. Whereas, USA accounted for 13%, topping the list. India ranked third in the list of worlds adult obese population. [Marie et al., 2014]. This has lead to a need to stress upon strategies to tackle obesity practically. An effective weight management intervention should involve a multidisciplinary team including a physician, dietician, exercise physiologist and behaviour therapist.

Current treatment approach is based on the individuals BMI and presence of co-morbid conditions.

1. Pharmacotherapy- Orlistat, is the drug which is approved by Food and Drug Administration (FDA) for individuals with a BMI >30kg/m^2 or BMI 27-29kg/m^2 with one or more co-morbid conditions and for Asian Indians pharmacological treatment should be initiated for BMI >27 kg/m^2 without co-morbidity, or a BMI > 25 kg/m^2 with co-morbidity. [Seagle et al 2009, A Misra et al., 2009, National Heart Lung and Blood Institute, 2012]
2. Surgery- Bariatric surgery is opted in morbid obesity in individuals with a BMI of 40kg/m^2 or more or a BMI between 35-39.9 kgandm2 along with a co-morbid condition such as type 2 diabetes, coronary heart disease, or severe sleep apnoea. However, for Asian Indians a BMI of >32.5 kg/m^2 with co-morbidity, and BMI >37.5 kg/m^2 without co-morbidity may require surgical intervention. [Seagle et al., 2009, A Misra et al., 2009, National Heart, Lung, and Blood Institute, 2012, National Institute of Health., 2009]
3. Diet- A reduction of 500-1000kcal/d is usually the first recommendation in the treatment of obesity. A daily reduction by 600kcal would result in weight loss by 0.5kg/week. However, energy restriction needs to be individualised. Reduction in caloric intake could either focus only on calorie count and/or macronutrient proportion along with changes in meal frequency, portion sizes and meal timing.

   The following diets are most commonly recommended:

(a) Hypo caloric balanced diets- These diets provide 1200kcal/day or more.

(b) Low calorie diet (LCD) – These diets constitute about 800-1200kcal/day

(c) Very Low Calorie Diet (VLCD) - These provide less than 800kcal/day and are typically liquid formulations. VLCD should not be used for long-term as they are associated with micronutrient deficiencies and should be supervised by a health professional [Constantine et al., 2008, Seagle et al., 2009].

This review summarizes the effects of use of Meal Replacers as a part of treatment approach for obesity.

Meal Replacers:

It is difficult to opt for a nutritious and low-calorie diet in an environment that provides a variety of energy-dense and nutritionally poor food choices. A lack of an effective long-term treatment which not only ensures weight loss but also weight maintenance has led to the development of meal replacements diets.[Robert et al., 2011] Meal replacers are commercially available products that provide fixed amounts of macronutrients and

micronutrients that may be used as a substitution of one or two main meals per day. Along with its ease of use, MR also prevents deficiencies commonly seen in LCD or VLCD thereby reducing the risk of fat deposition and obesity due to deficiency of certain micronutrients [Constantine et al., 2008, Seagle et al., 2009, National Obesity forum 2014, Alma et al., 2012]. Meal replacement plans also aid in the maintenance of lipid profile and blood sugars thus, reducing the incidence and magnitude of co-morbid conditions as a result of its effect on body composition (i.e. reduction in visceral fat mass).

Obesity is often accompanied by inflammatory responses. Visceral obesity is linked to an increased risk of insulin resistance, cardiovascular events and oxidative stress as a result of these inflammatory processes. C - reactive protein is an inflammatory marker and its elevated level is an independent predictor for endothelial dysfunction and cardiovascular diseases. The use of meal replacements have shown to reduce levels of C- reactive protein and other markers of systemic inflammation [Lisa et al., 2010].

Another predictor of cardiovascular events, homocysteine is also reduced by including meal replacers to a LCD or VLCD. This is mainly as a result of addition of folate and vitamin B12. Other ingredients such as dietary fibre may be added to a meal replacer for additional benefits on body weight. [Alma et al., 2012, Christine et al., 2011].

Meal replacement programmes are generally based on a daily intake of 1200-1500 kcal and enables to reduce 500-1000kcal/day [Seagle et al., 2009, National Obesity forum, 2014]. A structured meal replacement diet enables to lose equivalent or greater weight loss as compared to an isocaloric diet. This lost weight is also maintained better when combined with a healthy eating pattern and lifestyle modification.

Most interventions have shown a weight loss of about 2-4 kg in the first 6 months. Meal Replacers increase losses by 2.5kg and 2.4kg at 3 and 6 months respectively, as compared to an isocaloric diet of conventional foods. This may be attributed to the fact that inclusion of a meal replacer results in reduction to the ad libitum food choices consumed leading to decreased caloric intake. Meal replacement diets are also easy to monitor and evaluate as it contains known amounts of macronutrients and micronutrients. However on conventional diets individuals tend to underestimate their intake by 40-50% [Robert et al., 2011, Alma et al., 2012]

Obesity not only has clinical effects but also causes social stigmatization. Along with this obese individuals also suffer from psychosocial and physical functional impairments. This deteriorates the quality of life of individuals. A weight reduction of 5-10% in the first 6 months is recommended to achieve clinically significant results. Most trials evaluating the effects of meal replacers have shown this level of weight loss. [Seagle et al., 2009, National Heart Lung and Blood Institute, 2012, national Institute of Health, 2009, Alma et al., 2012, Christine et al., 2011, Renate et al., 2014]. Meal replacement diets can be used either as total meal replacement (TMR) or as partial meal replacement (PMR). Both TMR and PMR along with an overall lifestyle modification are effective, however, in the longer term PMR is more effective due to higher compliance. [Natasha J et al., 2013]

The effectiveness of meal replacers has been evaluated in several studies is shown in Table 3.

It is important to understand the physiological effects of Meal Replacers that are responsible in bringing about these beneficial outcomes in obese individuals.

Types and composition of meal replacers

The effect of major nutrients in MR on weight loss is discussed further.

Most meal replacers used for weight (fat) loss

have the following ingredients:

Protein Source : Whey protein (concentrate, isolate, hydrolysates)
Soy protein (concentrate, isolate, hydrolysates)

Carbohydrate: Maltodextrin
Fructose
Dietary fibres (oat fibre, inulin, psyllium husk)

Fat: Medium chain triglycerides
Omega-3

Along with these, MR are enriched with a blend of all essential vitamins and minerals and certain herbal extracts such as garcinia cambogia,, green coffee bean and green tea extract, ginger extract.

Impact of Composition of Meal Replacers on Weight Loss

The impact of meal replacement will be discussed with regards to each macro-nutrient. The holistic effects of meal replacement in obesity have been discussed previously.

Protein

The major limitation of most weight loss regimes is hunger and control of energy intake [Madalina et al., 2014]. Protein is considered to be the most satiating nutrient making it the major macronutrient in MR [Leo et al., 2008]. Whey and soy protein are most readily available protein sources and are implicated in regulating food intake [David J et al., 2011]. Casein also appears to play a role in fat loss [Sebely Pal et al., 2010]. A high protein diet (25% of energy) results in almost double amount of fat loss as compared to moderate protein diet (12% of energy) [Madalina et al., 2014]. The major advantage of protein is that it results in fat loss and preserves or maintains lean body mass. Some studies have also evaluated effects of Whey and Soy protein on co-morbid conditions such as Glycemic control, lipid metabolism and blood pressure regulation which can be attributed due to its effect on body composition and fat distribution.

Various mechanisms have been suggested for the role of protein on fat loss.

The major effect of whey protein on body weight is exhibited through its effect on appetite control and satiety [Leo et al., 2008, David J et al., 2011, Sebely Pal et al., 2010]. Whey protein has a direct impact on gut hormones PYY, GLP-1 and ghrelin. Whey protein results in an increase in PYY 3-36 and GLP-1 and reduction in ghrelin thus inducing satiety and reducing hunger which reduces energy intake and aids in weight loss [Leo et al., 2008, David J et al., 2011, Leila et al., 2011]

Along with these effects of whey, its faster rate of digestion and absorption and higher content of branched chain amino acids as compared to other protein sources (soy and casein) also results in greater fat loss [Sebely Pal et al., 2010]

Soy protein has similar effects on gut hormones. Soy isoflavones have a major role in glucose metabolism and in limiting lipotoxicity [Leila et al., 2011].

Current evidence on role of proteins in fat loss and body composition are shown in Table 4

It can be concluded that a high protein diet can have a beneficial effect on body fat and lipid profile of overweight and obese individuals. However, results on the amount and source of protein remain inconclusive.

Carbohydrates

The major source of carbohydrates in meal replacers is Dietary fibre. Dietary fibre refers to non digestible and non absorbable part of plant foods with complete or partial fermentation in the colon that result in production of short chain fatty acids (SCFA). These include insoluble fibre such as wheat bran and soluble fibres from oats, fruits and oligosaccharides [Huaidong Du et al., 2010, David M et al., 2014]

High fibre diets have been associated with beneficial effects on body weight by reducing energy intake and co-morbid conditions [Huaidong Du et al., 2010, Ellen et al., 2014]

Various physiological benefits of fibre have been evaluated for its effect on weight control, post-prandial glucose and hormonal responses, gastric emptying and intestinal transit time [David M et al., 2014]. Fibre rich diets tend to be more satiating as they slow down gastric emptying by forming viscous gel in the small intestine, which reduces absorption of nutrients, thereby prolonging satiety reduces post-prandial glucose and over a long term improves insulin sensitivity. An increase in the circulating level of Non esterified fatty acids (NEFA) and lipolysis is also seen. The SCFA produced interacts with G-Coupled protein receptors like GPR 41 & GPR 43 on the enteroendocrine L cells causing an increase in production of gut hormones; GLP-1 & PYY 3-36 [Huaidong Du et al., 2010, David M et al., 2014, Ellen et al., 2014, Sanne P et al., 2011] Various studies have analysed these effects of dietary fibre on changes in body weight and metabolic profile in obese individuals. Table 5 gives on overview of the effects of CHO in obesity. Higher total fibre intake is also inversely associated with waist circumference. Intake of 10 g/day of dietary fibre results in approximately 34% of mean weight change [Huaidong Du et al., 2010].

Striking the balance-Protein Carbohydrate Ratio

High protein diets are often used as a dietary strategy for weight loss. Most meal replacers are high protein formulas as protein has an advantage over other macronutrients in terms of being more satiating and maintaining body composition, improving lipid profile and insulin sensitivity [Leo et al., 2008, A. Calleja et al., 2012, .TP Wycherley et al., 2012]

An increase in protein content results in compensation of carbohydrates. Reduction in carbohydrate intake results in initial drastic weight loss as a result of diueresis and ketogenesis [Seagle et al., 2009], the resultant ketoneuria suppresses appetite causing reduced energy intake and therefore weight loss [Dawn D et al., 2012].

Fat, on the other hand has a weak effect on hunger and satiation and is also the most calorie dense macronutrient. Thus, a low fat diet (<30%) is the usual recommendation for weight loss [Seagle et al., 2009, TP Wycherley et al., 2012]

Although absolute weight loss may be a result of reduced energy intake rather than the macronutrient composition, but an ideal balance between protein and carbohydrates enables in better weight maintenance and compliance & reducing the intensity of co-morbid conditions. [A. Calleja et al., 2012, .TP Wycherley et al., 2012, Dawn D et al., 2012]. Therefore it is crucial to understand the protein carbohydrate ratio while suggesting a meal replacement on a hypo caloric diet.

However, most studies on an ideal protein to carbohydrate ratio for attaining and maintaining safe weight loss are inconclusive. Table 6 summarizes studies on an effective macronutrient composition.

Thus, a protein to carbohydrate ratio of 1:2 in meal replacements may be beneficial for achieving weight loss and maintaining a better metabolic profile in obese individuals. As the benefits of normal protein intake are almost same as high protein, unnecessarily increasing protein for a long term might further deteriorate health outcomes by having a negative impact on bone mineral density and renal system [Russell J et al., 2012] This should be critically analysed as obese individuals are already more prone to osteoporosis and impairment in renal function. Further studies to establish an ideal ratio in meal replacers are recommended.

Herbal extracts

Many herbal extracts are now being used as fat burners in meal replacers or otherwise. These include ginger extracts, green tea and coffee bean extracts, guggul, hoodia, garcinia

combogia and piperine.

This article will discuss the effects of green tea extract and garcinia combogia on fat oxidation.

Green Tea Extract and fat loss

The effect of green tea on fat loss is mainly due to its polyphenols which are classified as flavonoids (catechins in tea), and non flavonoids (chologenic acids in coffee). These polyphenols act as antioxidants in many chronic conditions. As inflammatory reactions are key events responsible for obesity, they exhibit a beneficial effect. Several studies have documented weight loss via fat oxidation through the use of catechins and chologenic acid however the exact quantity that leads to fat oxidation remains unidentified. Green tea catechins include epicatechin, epigallocatechin gallate. These compounds tend to influence Nitric Oxide production thus, causing vasodilation. Therefore, these extracts also have a profound effect in individuals suffering from hypertension and endothelial dysfunction.

The anti-obesity effects of catechins may also be mediated by the modulation of adipogenesis and nutrient absorption. Long term use of catechins reduces fat absorption thereby reducing overall fat availability. Fat metabolism may also be affected via inhibition of hormone sensitive lipase thus, increasing fat oxidation. Catechins also reduce carbohydrate metabolism through inhibition of glucose transporters GLUT 4 and SGLT 1. Lastly, catechins are found to increase the activity of the gene signal AMPK (5' adenosine monophosphate-activated protein kinase). AMPK is involved in fat oxidation by cells. The quantity of catechins present in green tea (or coffee) would differ according to the geographical soil quality. This is one of the reasons for inconclusive results on its quantity [Noriyasu et al., 2010, R. Hursel et al., 2010, A. L. Brown et al., 2011]

Garcinia Combogia extract

Natural food supplements containing garcinia combogia have been extensively promoted as possible weight loss aids. Garcinia combogia is a rich source of hydroxycitric acid (HCA).HCA is a potent inhibitor of pancreatic alpha-amylase and intestinal alpha-glucosidase. This leads to a reduction in carbohydrate metabolism. HCA also inhibits the enzyme adenosine triphosphate citrase-lyase and increases the availability of serotonin thereby leading to appetite suppression. Besides, HCA also directly interacts with adipocytes causing lipid droplet dispersion and altering transcription. Another bioactive component, benzophenones are also reported to reduce oxidative stress. However, studies of garcinia combogia in humans with its safe use are lacking therefore this needs further research owing to its associated health benefits in animal and some human studies.[Ji-Eun Kim et al., 2011, Igho et al., 2010]

Conclusion

A practical nutrition therapy for the treatment of obesity & associated complications is the need of the hour to assist individuals in weight loss and maintenance. The major issue with most conventional weight loss strategies is compliance to the diet and prevention of sarcopenic obesity. Meal Replacers may be used as an important facilitator especially in the initial phase and in diets where nutrient density and compliance on a weight loss diet becomes a concern. The user should get a complete insight on the ingredients and nutrient composition and thus nutrition labelling of such products helps in making informed choices by the individual under professional care. The use of meal replaces in the diet should be done under the guidance of a nutritionist so that the quantum and frequency may be customised to the individual's nutrient needs.

There is a felt need to generate evidence based

Indian data especially in relation to the quantity and safe levels of herbal supplements added to these formulations so that there is increased science available for their safe, effective and optimal usage in weight loss. Thus meal replacers can play a significant role along with a structured weight loss program in dropping the rates of obesity in the present obesogenic environment.

Table 1: BMI guidelines [WHO, 2008, Misra et al., 2009]

BMI	Category	Guideline
25.0 - 29.9 kg/m^2	Overweight	WHO
≥30kg/m^2	Obesity	WHO
23-24.9 kg/m^2	Overweight	A Misra et al., 2009 (Guidelines for Asian Indians)
>25 kg/m^2	Obesity	A Misra et al., 2009 (Guidelines for Asian Indians)

Table 2: Age-wise prevalence of overweight & obesity in Indians [Marie et., 2014]

Age	Sex	Overweight	Obesity
<20 years	Males	5.3%	2.3%
>20 years	Males	19.5%	3.7%
<20 years	Females	5.2%	2.5%
>20 years	Females	20.7%	4.2%

Table 3: Effects of Meal Replacers on weight loss & other metabolic risk factors

Study	Subjects & Study design	Results and Conclusion
Davis et al., 2010	40-week randomized, controlled clinical trial. 90 obese subjects. Interventions consisted of two groups: 1) MR program (MD group) for weight loss and weight maintenance 2) Self-selected, isocaloric, food-based meal plan (FB).	x At 16 weeks, average weight loss in MD (12.3%) was almost double as compared to FB (6.7%). MD group lost almost 5 times more body fat and 7 times more visceral fat as compared to FB group. x At week 40, plasma CRP

Study	Subjects & Study design	Results and Conclusion
		levels decreased by 40.7% and 30.1% for the MD and FB groups respectively. x Overall 93% subjects lost clinically significant weight along with favourable effects on body composition and inflammatory markers with MR
Berkowitz et al., 2011	12-month randomized trial 113 obese adolescents. Interventions groups consisted of: 1) Self-selected foods consisting of 1,300-1,500kcal/d (CD) 2) MR	x No statistically significant differences between the groups in blood pressure, lipid profile, and glucose and insulin homeostasis were seen x In both groups, mean reduction in BMI at 12 months was 3.4 ± 0.7% ($P < 0.01$). x Meal replacer group lost 7.5% as compared to only 5% by the conventional hypoenergitic diet at the end of 12 months.
Metzner et al., 2011	12-weeks open-label, randomized, controlled study. 87 subjects. Intervention groups: 1) Energy restricted diet with MR 2) Energy restricted diet without MR (C)	x Both groups showed similar weight loss and body fat distribution but, the responder rate was higher in MR (77%) as compared to C (50%) x One kg weight loss resulted in a reduction of systolic and diastolic by 2.0 and 1.1 mmHg respectively x Thus, MR can be used for delaying or preventing the onset of cardiac events in obese individuals

Study	Subjects & Study design	Results and Conclusion
D.-F. Xu et al., 2013	12-month randomised prospective study. 82 IGR subjects Intervention groups: 1) Dietary restrictions 2) Dietary restrictions along with a low Glycemic Index MR	x The use of MR resulted in a significant weight reduction ($p<0.05$). 74% of this weight loss was due to loss of fat mass x MR group showed reduction in HbA1c ($p<0.02$). x A 5kg decrease in body weight at the end of 1 year, reduced 2 hr post-prandial glucose by 1.49mmol/L. x With the use of meal replacement 39.0% subjects reverted to normal glucose tolerance as opposed to 7.5% in the control group.
Koohkan et al., 2014	12-month controlled trial. Intervention groups: 1) Lifestyle program without a MR (LS) 2) Same lifestyle program with a soy-based MR (LSMR)	x LSMR showed greater weight reductions x LSMR showed greater improvements in Health Related Quality of Living ($p< 0.01$)

Table 4: Evidence on role of proteins in fat loss and body composition

Study	Subjects & Study Design	Results & Conclusion
Treyzon et al., 2008	Single blind, placebo-controlled, randomized outpatient weight loss trial. 100 obese men and women Intervention groups: 1) Isocaloric Meal plan with High Protein (2.2g/kg BW) MR (HP) 2)) Isocaloric Meal plan with Standard Protein (1.1g/kg BW) MR (SP)	x Weight loss achieved was similar in both groups. However HP lost more body fat (HP:$1.65_{\pm}0.63$ kg; SP= -0.64 ± 0.79 kg) x HP group showed greater losses in LDL & Total cholesterol (HP: $p<0.05$ SP: $p>0.05$)

Study	Subjects & Study Design	Results & Conclusion
S.Pal et al., 2010	12 weeks randomised, parallel design. 89 Obese & overweight men & women Three groups: 1) 27g whey protein isolate 2) 27 g sodium caseinate 3: Control: 27g glucose	x No overall significant differences were seen in anthropometry x Total cholesterol and LDL cholesterol decreased by 7% in the group supplemented with whey protein at week 12.
Baer et al., 2011	23 weeks Double-blind, randomized clinical trial 90 overweight and obese free-living individuals 3 Treatment groups 1) Supplemental whey protein (56g proteins/d) 2) Supplemental Soy protein (56g proteins/d) 3) Isoenergitic CHO	x Body weight and fat of the group consuming WP were lower by 1.8 kg ($P < 0.06$) and 2.3 kg($P < 0.05$) respectively than the group consuming CHO x Waist circumference and fasting ghrelin were lower in the WP group as compared to SP and CHO

Table 5: Carbohydrates in MR

Study	Type of CHO	Study Design	Results & Conclusion
Savastano et al., 2014	Pectin and oligosaccharides (OFS) effect on insulin sensitivity	Single centre, randomized, double-blind, placebo-controlled, parallel group study 3 treatment groups; 1) High dose (5 g OFS + 5 g pectin. 30g/d) 2) Low dose (2.5 g OFS + 2.5 g pectin. 25g/d) 3) Placebo (2.5 g + 2.5 g maltodextrin)	x Fasting insulin was reduced by 16% in high dose and by 12% in low dose group. x Mean insulin AUC was reduced by 10% in high dose and by 17% in low dose group
S. P. M. Verhoef et al., 2011	Oligofructose supplementation on appetite profiles & satiety hormone	13 days Randomised, placebo-controlled cross-over Design 31 healthy subjects 1) 10 g oligofructose, 2) 16 g oligofructose 3)16 g placebo period	x 16 g/day of OFS significantly reduced fasting PYY concentration & energy intake (11%, $p<0.05$

Study	Type of CHO	Study Design	Results & Conclusion
E. Konings et al., 2014	Substitution 30% of available carbohydrate with polydextrose and soluble maize fibre	Single-blind, randomised crossover study 18 overweight men and women Intervention: 2 fibre diets with polydextrose and soluble maize fibre and two controlled diets (full energetic and iso energetic).	x The peak glucose response was lower & fat oxidation & NEFA response increased after consumption of both fibre diets as compared to the controlled diets. x Polydextrose diet resulted greater fullness and satiety over 24 hours
Martin de Bock et al., 2012	Psyllium supplementation on metabolic profile	6 weeks Participant-blinded, randomized, placebo-controlled, crossover trial 457 healthy adolescent males Intervention: 1) 6g psyllium 2) Placebo	x 4% reduction in android fat to gynoid fat ratio (p=0.019) and a 6% reduction in LDL cholesterol. x Psyllium improved fat distribution and lipid profile in an at risk population of adolescent males.

Table 6: Protein: Carbohydrate ratio

Study	Study Design	Intervention	Results & Conclusion
D. D. Campbell and K. A. Meckling, 2012	12 weeks Randomized interventional study 54 overweight & obese women with MetS	1) Low protein (LP, 1 g protein:4 g carbohydrate), 2) Normal protein (NP, 1 g protein:2 g carbohydrate) 3) High protein (HP, 1 g protein: 1 g carbohydrate)	x Weight losses in low protein, normal protein, and high protein were 6.2, 8.9 and 7.1 kg respectively x Loss of total body fat and waist circumference was higher in NO as compared to LP. x NP intake (1:2) has a better overall effect on markers of obesity.

Study	Study Design	Intervention	Results & Conclusion
De souza et al., 2012	Randomized trial	1. Low fat, average protein (20% fat. 15% protein, 65% carbohydrate) 2. Low fat, high protein (20% fat. 25% protein, 55% carbohydrate) 3. High fat, average protein (40% fat. 15% protein, 45% carbohydrate) 4. High fat, high protein (40% fat. 25% protein, 35% carbohydrate)	x Participants in all dietary interventions lost more fat than lean mass. No significant differences x All the four dietary interventions consumed saturated fat ≤ 8%, dietary fibre ≥ 20 g/day and cholesterol <150 mg per thousand kcal with low Glycemic index foods and a energy deficit of 750 kcal/day from estimated energy requirements, thus indicating that subjects lost weight as result of the overall caloric restriction and improved quality of diet.
TP Wycherley et al., 2012	Randomised parallel study design 68 subjects	Iso energetic intervention groups: 1)High protein diet consisted of 35% protein, 40% carbohydrate and 25% fat 2) High carbohydrate consisted of 17% protein, 58% carbohydrate and 25% fat.	x The high protein group lost less fat free mass ($p<0.0001$). x At week 52, subjects in high protein group lost -2.6±3.7 kg fat free mass vs. -3.8±4.7 kg for high carbohydrate group. x High protein group resulted in better improvements of body composition.
A. Calleja Fernández et al.	1 year randomised, prospective, clinical intervention 40 obese individuals with either insulin resistance or insulin sensitivity	1) 40% carbohydrate, 30% protein, 30% fat 2) 55% carbohydrate, 15% protein, 30% fat	x At 6 weeks no differences in weight loss was seen x At 1 year the lost weight was better maintained by subjects in the insulin sensitive group ($p= 0.04$) thus depicting a co-relation between insulin sensitivity & obesity

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