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Comparison of recommended daily calorie from Carbohydrates using the Conventional Total Daily Energy Expenditure (TDEE) Formula with The Proposed Maximum Carbohydrate per Day (MCPD) formula in an adult population of South Gujarat

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Abstract
Background: Recommended calorie requirement per day depends upon work done by the individual per day and metabolic conditions. As per WHO and USDA 45-65% carbohydrates in diet is recommended, but in India, most people relay upon cereals for food. So we need to find an upper limit for carbohydrate consumption to prevent diabetes in our society.
Objectives: 1. To compare the results of the Maximum Carbohydrate per Day (MCPD) formula with current Total Daily Energy Expenditure (TDEE) formula.
Methods: The study population is people attending Niramaya camp at Surat Medical College and Hospital. Sample size is 122. The individuals are evaluated for vitals, FBS, FLP, BMI, BMR, eating habits, physical activity, addictive habits and other co-morbidities. Results by both the formulae are plotted on graph to find the Pearson's coefficient of association.
Results: Pearson's coefficient obtained is 0.17 for males and 0.40 for females, which is because, the results obtained by TDEE formula are not adjusted for subclinical metabolic disorders and physical activity as it is difficult to classify work done as light, moderate or high for activity factor.
Conclusion: MCPD formula can recommend a low-carbohydrate diet for obese, pre-diabetic and pregnant women prone to gestational diabetes when compared to TDEE formula. MCPD represents a metabolically modulated energy recommendation, incorporating glycaemic handling capacity, whereas TDEE estimates energy expenditure based primarily on physical activity. However further study on diabetic and pregnant subjects has to be done to test the hypothesis and validate the formula for clinical use.

Keywords: Calorie, BMR, balanced diet, energy density, diabetes diet, pregnancy diet, metabolic dysfunction

Introduction

The doubly labelled water method is the gold standard method for calculating Total Daily Energy Expenditure. The subjects are enriched with doubly radioactive labelled water with heavy hydrogen(^2H) and heavy oxygen(^{18}O) and then determine washout kinetics of both the isotopes to determine the CO_2 production, which in turn allows us to calculate approximate total energy used [1]. The doubly labelled water method is the indicated method for measuring energy expenditure in any environment especially activity energy expenditure. Its applications include validation of dietary assessment methods and validation of physical activity assessment [2]. Direct calorimetry is used for measuring human metabolic rate. It quantifies the aerobic and anaerobic metabolism by measuring the heat exchange between the body and the environment. Applications include understanding energy balance, nutrition and pathogenesis of metabolic diseases [3]. Indirect calorimetry is also widely established method to assess energy expenditure, which is derived from the rate of substrate depletion [4]. Routine use of indirect calorimetry can be used to optimize patient care [5].Indierct calorimetry can also be used to understand and predict obesity [6]. In humans, variation in resting metabolic rate might be linked to health-related conditions [7]. Basal Metabolic Rate is the energy expenditure by the body when the individual is at rest. It is affected by various

factors including body weight, health status, body composition, age, race, gender, biochemical parameters and physical activity [8]. It is calculated using Mifflin-St Jeor Equation for both males and females separately [9]. Sedentary individuals are defined as individuals carrying out normal daily chores without involving in exercises or hard work. Their energy expenditure will be slightly more than BMR which can be calculated using Total Daily Energy Expenditure (TDEE) formula as 1.2*BMR. Like this TDEE for light, moderate and heavy work can also be calculated using TDEE formula. But this formula does not consider underlying metabolic conditions like diabetes, goitre, hyperthyroidism, stress, adrenal insufficiency, Cushing's syndrome etc. Thus, it becomes difficult for a nutritionist to prescribe the correct dietary requirement for an individual especially pre-diabetic. And energy requirement for women is less than that for men, TDEE have provision to calculate this [10].Gestational Diabetes is one of the dangerous complications in pregnancy. Gestational weight gain is the most important and independent risk factor for gestational diabetes mellitus [11]. Pregnant women are advised to consume energy dense food in early pregnancy to enhance foetal growth. But following diet, calculated using TDEE formula, without checking FBS, can result in increased chance of acquiring gestational diabetes in the second or third trimester. Thyroid hormones have strong effects on cardiovascular and metabolic functions [12]. Many metabolic conditions like hyperthyroidism and goitre also need to be evaluated before prescribing diet for proper weight management. Subclinical insulin resistance and beta cell dysfunction also make it difficult to define the precise calorie needs using TDEE formula. It is also very difficult to accurately define light, moderate and heavy work according to duration and intensity of work [13]. Energy is utilized by cells, muscles and brain. So only considering physical activity cannot accurately account for work done per day. We are here comparing a new formula for finding maximum carbohydrate limit per day for an individual, that is, Maximum Carbohydrate per Day (MCPD) to help people orchestrate diet plans for weight loss, gain or to maintain adequate weight to ensure proper health.

Methods and Materials

Study populations

The study was conducted at the New Civil Hospital, Surat, located in the South part of the Gujarat in India. It is a government hospital with people consulting ranging every class of the society. Our study population included people attending Niramaya health camp which is conducted to screen for prevalence of any health condition in the Police officers of the Surat District. Our sample size is 122. The sample size included individuals ageing from 18 years till 45 years of both sexes. No one is excluded from the study.

The sample population is surveyed for age, height, weight, weight circumference, eating habits, physical activity, addictive habits and other comorbidities, and evaluated for pulse rate, blood pressure, fasting blood sugar, fasting lipid profile including total cholesterol, HDL, LDL, triglycerides, BMI and BMR.

Statistical analysis

The Formula for Maximum Carbohydrate per Day (MCD) is given by,

MCD= $BMR^2/(15.5*FBS)$ in males
MCD= $BMR^2/(14.4*FBS)$ in females

Physiological Basis of Sex-Specific CPD Constants

Females have lower lean mass, higher insulin sensitivity variability and lower glucose oxidation rate at rest. The lower denominator used in females reflects known sex-related differences in basal metabolic efficiency and glucose utilization, which are not captured by standard activity-based energy equations.

Recommended calorie from carbohydrate is 50% of calculated total calorie requirement per day. Calorie from carbohydrate requirement per day calculated by current formula [14]:

$$\text{TDEE} = \text{BMR} \times \text{Activity Factor} \times 0.5$$

BMR is calculated using Mifflin-St Jeor Equation

For Men

BMR = (10 × weight in kg) + (6.25 × height in cm) - (5 × age in years) + 5

For Women

BMR = (10 × weight in kg) + (6.25 × height in cm) - (5 × age in years) - 161

Activity Factor is determined by multiplying BMR by the following factor based on the activity level

1. **Sedentary:** Little to no exercise (BMR x 1.2).
2. **Lightly Active:** Light exercise or sports 1-3 days/week (BMR x 1.375).
3. **Moderately Active:** Moderate exercise or sports 3-5 days/week (BMR x 1.55).
4. **Very Active:** Hard exercise or sports 6-7 days/week (BMR x 1.725).
5. **Extra Active:** Very hard exercise, a physical job, or a twice-a-day training session (BMR x 1.9).

The results obtained using the two formulas is plotted in the graph against each other to find the Pearson's coefficient of association. Linear regression analysis is done to predict the agreement in results.

Results

Baseline characteristics

Table 1: Clinical and laboratory characteristics of the study in males [15]

Characteristics	Mean Value	Reference Unit
Males	79	individuals
Age	32+/-6	years
Height	1.7+/-0.06	m
Weight	67.53+/-10.09	kg
BMI	23.43+/-4.01	kg/m^2
WC	33.11+/-2.94	inch

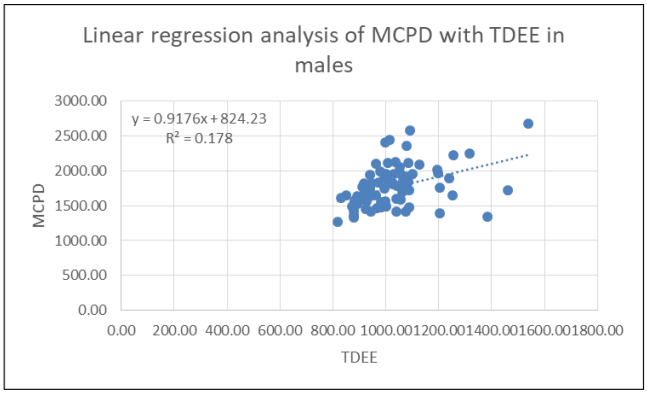
Cholesterol	202.22+/-37.14	mg/dL
Triglycerides	136+/-92.79	mg/dL
LDL	122.78+/-30.28	mg/dL
HDL	53.56+/-8.46	mg/dL
FBS	93.03+/-10.78	mg/dL
Systolic BP	115.51+/-9.12	mmHg
Diastolic BP	73.56+/-7.61	mmHg
TDEE	1024.56+/-136.69	kcal/day
MCPD	1764.40+/-297.31	kcal/day
BMR	1582.9+/-104.6	kcal/day

Abbreviations: BMI Body mass index, HDL high-density lipoprotein, LDL Low-density lipoprotein, BMR Basal Metabolic Rate, FBS Fasting Blood Sugar, WC- waist circumference

Table 2: Clinical and laboratory characteristics of the study in females [15]

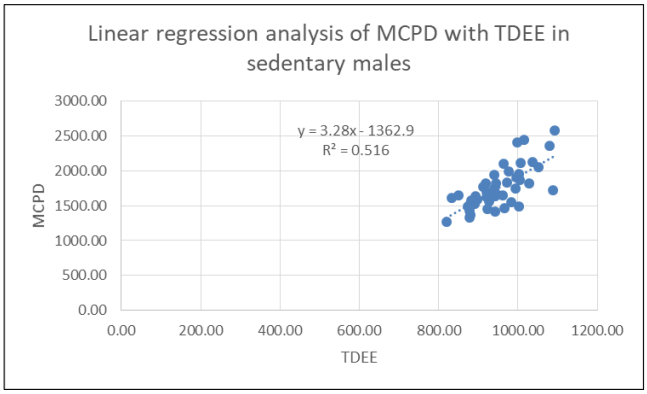
Characteristics	Mean ± SD	Unit
Age	30.41 ± 6.07	years
Height	1.60 ± 0.04	m
Weight	57.27 ± 9.76	kg
Body Mass Index (BMI)	22.38 ± 3.57	kg/m²
Waist Circumference (WC)	31.50 ± 2.70	inch
Total Cholesterol	186.24 ± 32.94	mg/dL
Triglycerides	86.58 ± 33.96	mg/dL
Low-Density Lipoprotein (LDL)	112.68 ± 33.47	mg/dL
High-Density Lipoprotein (HDL)	57.70 ± 10.25	mg/dL
Fasting Blood Sugar (FBS)	90.48 ± 14.89	mg/dL
Systolic Blood Pressure	111.86 ± 5.64	mmHg
Diastolic Blood Pressure	72.27 ± 6.19	mmHg
Total Daily Energy Expenditure (TDEE)	794.41 ± 81.28	kcal/day
Measured Caloric Production per Day (MCPD)	1255.51 ± 205.48	kcal/day
Basal Metabolic Rate (BMR)	1424.97 ± 105.83	kcal/day

Abbreviations: BMI Body mass index, HDL high-density lipoprotein, LDL Low-density lipoprotein, BMR Basal Metabolic Rate, FBS Fasting Blood Sugar, WC- waist circumference



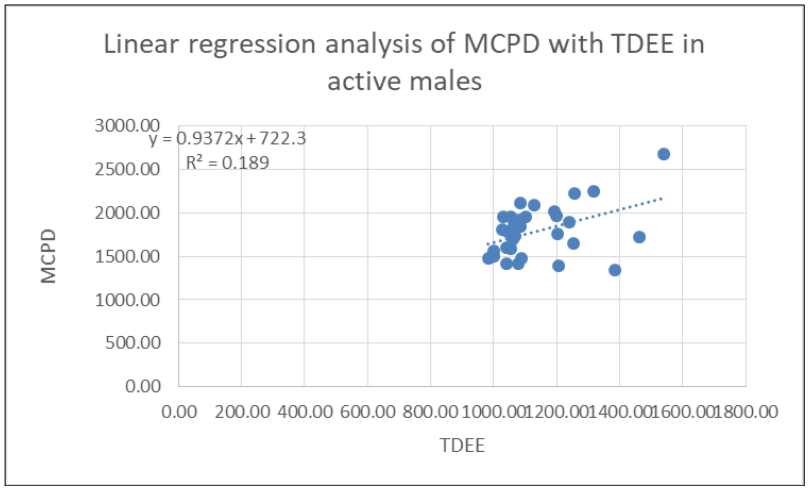
Graph 1: Linear regression analysis to find any association of TDEE with MCD in males

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure



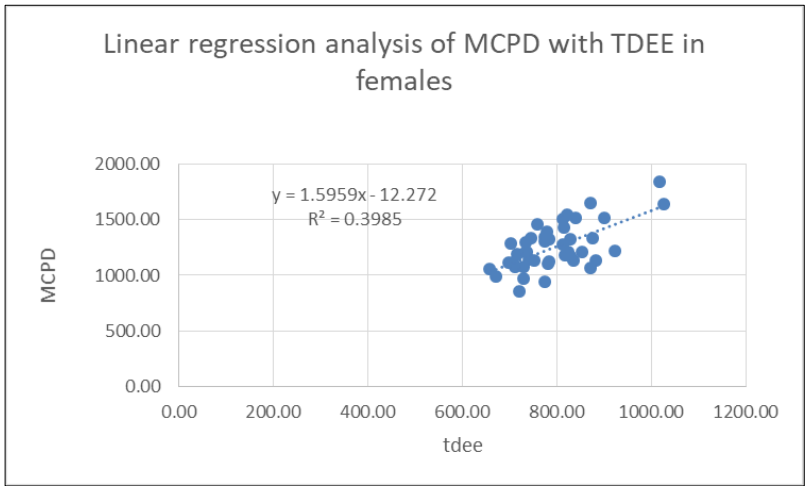
Graph 2: Linear regression analysis to find any association of TDEE with MCD in sedentary males

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure



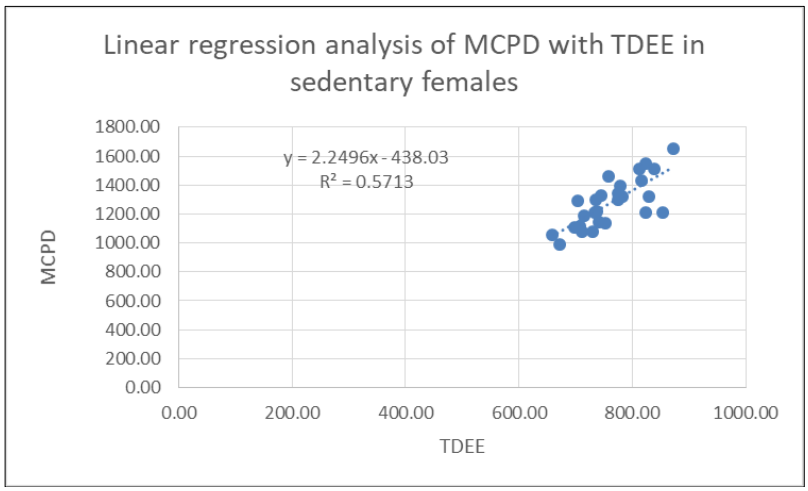
Graph 3: Linear regression analysis to find any association of TDEE with MCD in active males

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure



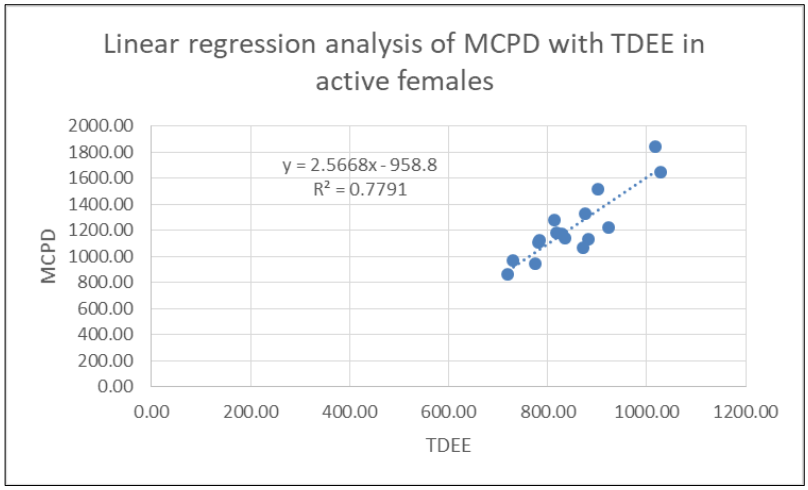
Graph 4: Linear regression analysis to find any association of TDEE with MCD in females

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure



Graph 5: Linear regression analysis to find any association of TDEE with MCD in sedentary females

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure



Graph 6: Linear regression analysis to find any association of TDEE with MCD in active females

Abbreviations: MCPD- Maximum Carbohydrate Per Day, TDEE- Total Daily Energy Expenditure

Table 3: Association of MCPD with TDEE in active, sedentary and total males and females

Groups	Coefficient of association between MCPD and TDEE
Total males	0.17
Sedentary males	0.51
Active males	0.18
Total females	0.39
Sedentary females	0.57
Active females	0.77

Discussion

From the graph, Pearson's coefficient obtained is 0.17 Graph.1 for males and 0.39 Graph.4 for females. Pearson's coefficient of determination is 0.51 Graph. 2, 0.57 Graph.5 in sedentary males and females, which is because the current TDEE formula does not take into consideration diabetes, or other underlying metabolic disorders. Pearson's coefficient is 0.18Graph.4 in active males and 0.77Graph.6 in active females which implies that, it is difficult to define accurately the work done per day by an individual as light, moderate or high with good precision. However, doubly labelled water method, direct or indirect calorimetry methods has to be used for validation of the results obtained by MCPD formula which requires further study.

From the data, it is evident that the maximum carbohydrate limit is nearly equal or slightly less than the total daily energy expenditure from all the nutrients combined. So, when we consider the Indian population, which mainly depend upon carbohydrate rich diet, MCPD gives a boundary to limit the carbohydrate intake at the same time ensuring adequate energy requirement necessary for the day-to- day activities. Calorie difference between TDEE and MCPD has to filled by proteins, fats to ensure proper functioning of the body. This proposed study is purely based on metabolism. The MCPD formula takes into consideration Fasting Blood Glucose, unlike current TDEE formula. Individual who are obese and pre-diabetic should be administered with low calorie diet. As per TDEE formula the calorie requirement from carbohydrate for pregnant women especially in the first trimester can be very high. The MCPD formula takes into consideration FBS, predicting the chances of developing gestational diabetes in the 2nd or 3rd trimester. The proposed formula can also calculate maximum carbohydrates, tolerable by subclinical thyroid patients and for patients with metabolic disorders. So, the proposed formula can be used as a tool to complement conventional method by nutritionists to verify their diet plan and to rule out subclinical pre-diabetes or thyroid disorders.

Conclusion

MCPD determine maximum limit of carbohydrate for an individual per day, which is limit to prevent obesity, taking into consideration their metabolic state and ability to utilise the consumed Calorie. Calorie as we say is mostly derived from carbohydrate metabolism even though fats and proteins can also contribute from their respective metabolism. Proteins or amino acids take part in enzymes and structural proteins synthesis and maintenance. Fats are used for cellular membrane synthesis and maintenance and also as storage molecules of energy. Diabetes is caused by impaired glucose metabolism. So, in this condition, the subject should be administered with low calorie diet, meaning diet which comprises of less amount of carbohydrates and fats and more amount of proteins, unsaturated fats, fibres and water. This will help the individual to maintain the blood glucose level as normal as possible. MCPD can help nutritionists to detect subclinical metabolic conditions and also to cross check their calculations. However, further study on diabetic and pregnant subjects has to be done to test the hypothesis and validate the formula for clinical use.

Abbreviations

- **BMI:** Body mass index
- **MCPD:** Maximum Carbohydrate Per Day
- **TDEE:** Total Daily Energy Expenditure
- **HDL:** High-density lipoprotein
- **LDL: N** Low-density lipoprotein
- T2DM Type 2 diabetes mellitus
- BMR Basal Metabolic Rate
- FBS Fasting Blood Sugar
- WC Waist circumference
- BP Blood Pressure

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Ethical committee approval is acquired from the ethical committee of Government Medical College Surat for the study on parameters affecting diabetes patients. All the tests are done at New Civil Hospital, laboratory. Patients attending Niramaya camps are surveyed through Questionnaire.

Conflict of Interest Statement: The author declares that there is no involvement of any third-party funding or interest in this research.

Authors Contributions: All the authors contributed equally to the research

Ethical considerations

The required consent is acquired from the ethical committee of Government Medical College, New Civil Hospital, Surat, Gujarat, India. Data is collected from patient reports and questionnaire were done for age, weight, height, eating habits, physical activity and other co-morbidities. All the participants were informed about the study. The study is cross sectional and no follow up was required.

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