Application of Linear Equations to Analyze Caloric and Macronutrient Requirements in Fitness Programs for Cutting, Bulking, and Body Recomposition

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Abstract*—The application of linear equations to investigate and maximize caloric and macronutrient needs for three main fitness goals—cutting, bulking, and body recomposition—is investigated in this work. Given the growing interest in nutrition and exercise, accurate and flexible approaches for computing nutritional requirements have become ever more critical. The suggested approach uses linear equations to offer a methodical foundation for customizing diet regimens depending on personal criteria including basal metabolic rate (BMR), activity level, and fitness goals. Emphasizing the balance between protein, carbohydrates, and fats, we create equations to estimate macronutrient distribution and calorie consumption using accepted nutritional guidelines. Hypothetical case studies comparing results for people with different fitness goals help to validate the approach. The stress model requires calorie deficits for reducing programs, but it keeps enough protein to maintain lean muscle. Calculating calorie surpluses with an eye on maximizing muscle building and reducing fat accumulation helps bulking programs. Through calculated calorie and macronutrient changes, the model combines a dynamic strategy to balance fat loss and muscle gain for body recomposition. The results show that a scalable and flexible method for customized nutrition planning is provided by linear equations. By offering a mathematical basis for trainers, fitness enthusiasts, and researchers to approach nutrition more analytically, this work closes the theoretical and practical divide. The integration of machine learning methods to improve the adaptation of these equations for various populations and dietary preferences will be the main emphasis of next research.

***Keywords*—linear equations, caloric requirements, macronutrient distribution, cutting, bulking, body recomposition, fitness programs.**

I. Introduction

Regular physical activity and a suitable diet help two main factors greatly affect fitness goals including weight reduction (cutting), muscle mass growth (bulking), or changes in body composition (body recomision). The body runs on nutrition to maintain physical activity, heal damaged muscle tissue, and maximize metabolic processes. But depending on gender, age, weight, height, degree of physical activity, and particular fitness goals, dietary needs differ significantly among people.

Mathematical approaches such the use of linear equations have become well-liked for evaluating dietary requirements as nutritional research and technology develop. By modeling interactions between factors like body weight, activity levels, and fitness goals, linear equations let one precisely estimate caloric needs and macronutrient distributions (carbohydrates, proteins, fats). Linear equations can help to build customized food regimens in the setting of fitness. This method helps to determine daily macronutrient and calorie needs as well as the ideal ratios required to support programs for body recomposition, bulking, or reducing. It offers an easily available framework for pragmatic uses in addition to a simple, scientifically based approach for developing measurable dietary programs.

The misallocation of macronutrients is one of the most often encountered obstacles for those aiming at fitness. Frequent mistakes in estimating calorie or protein needs as well as in ignoring appropriate carbohydrate and fat ratios abound. Many times, lack of thorough knowledge of sports nutrition leads to these errors. Furthermore complicating good nutritional planning is the lack of precise, simple-to-use tools.

This work aims mostly to create a mathematical model based on linear equations to forecast individual calorie and macronutrient requirements using personal weight data. Moreover, this work suggests the creation of a web application depending on the chosen exercise program that computes the necessary consumption of protein, fat, carbs, and total calories. This work hopes to help people reach their fitness and health objectives by offering exact and useful tools for nutritional planning.

A basic idea in linear algebra, linear equation systems find extensive use in mathematics, physics, engineering, economics, and computer science among other fields. Applying this idea to programs in cutting, bulking, and body recomposition will help one ascertain the necessary consumption of fat, carbs, and protein for particular fitness goals. For instance, first calorie needs calculated from past studies can act as a baseline if someone weighing 67 kg wants to pursue a reducing program. By means of a system of linear equations, the exact carbohydrate needs can be computed depending on the known caloric values of every macronutrient, therefore guaranteeing a balanced and efficient dietary program.

II. Basic Theory

A. System of Linear Equation Definition

A system of linear equations is a set of linear equations whose variables do not contain exponentials, trigonometric functions (such as sin, cos, etc.), multiplication, division by other variables or itself. In other words, each equation in this system only involves addition, subtraction, and multiplication operations between constants and variables.

A system of linear equations can consist of a number of interrelated equations and have a limited number of independent variables.

B. The general form of a system of linear equations with m equations and n variables x1 , x2, …, xn:

1. Ax=b form

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n &= b_1 \\ a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n &= b_2 \\ \vdots \qquad \vdots \qquad\quad \vdots \quad &\quad \vdots \\ a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n &= b_m \end{aligned}$$

Fig. 1. Ax=b form (Source: [1])

2. Matrix form

$$\begin{bmatrix} a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \\ a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \\ \vdots \qquad \vdots \qquad \vdots \\ a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}$$

Fig. 2. Matrix form (Source: [1])

3. Multiple of matrix form

$$\underbrace{\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix}}_{\mathbf{x}} = \underbrace{\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}}_{\mathbf{b}}$$

Fig. 3. Multiple of matrix form (Source: [1])

4. Augmented matrix form

$$[A \mid \mathbf{b}] = \left[\begin{array}{cccc|c} a_{11} & a_{12} & \cdots & a_{1n} & b_1 \\ a_{21} & a_{22} & \cdots & a_{2n} & b_2 \\ \vdots & \vdots & & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} & b_m \end{array}\right]$$

Fig. 1. Augmented matrix form (Source: [1])

C. Gauss Elimination Method

The Gaussian elimination method is a way to solve a system of linear equations by changing the augmented matrix into a simpler version, specifically the row echelon form. A matrix is considered to be in row echelon form if it satisfies these specific conditions [3] :

1. If a row has any nonzero elements, the first one should be 1, which is referred to as the “leading one.”

2. If there’s a row where all the elements are zero, that row should be moved to the bottom of the matrix.

3. Each “leading one” in the lower row is positioned in the rightmost column compared to the “leading one” in the upper row.

$$\begin{bmatrix} 1 & * & * & * \\ 0 & 0 & 1 & * \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad \begin{bmatrix} 0 & 1 & * & * & * \\ 0 & 0 & 0 & 1 & * \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Fig. 4. Eselon Row Matrix (Source: [3])

To form a row echelon matrix, we use elementary row operations (OBE), which include three different types of operations.

1. Multiply one row by a non-zero number.
2. Swapping two rows.
3. Adding multiples from one row to another row

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} & b_1 \\ a_{21} & a_{22} & \dots & a_{2n} & b_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} & b_n \end{bmatrix} \sim\text{OBE}\sim \begin{bmatrix} 1 & * & * & \dots & * & * \\ 0 & 1 & * & \dots & * & * \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \vdots & 1 & * \end{bmatrix}$$

Fig. 5. Gauss Elimination Method (Source: [3])

Once the matrix is simplified to row echelon form, you'll end up with a set of equations that are simpler to solve. The solution to the system of equations can be found easily through back substitution.

D. Nutrition in Fitness

Calories: A calorie is a unit of energy required by the body to perform physiological functions and physical activities[4]. To maintain body weight, a person needs to consume calories according to their Total Daily Energy Expenditure (TDEE) [4].

Total Daily Energy Expenditure (TDEE), which shows the total number of calories the body burns in a 24-hour period, is tightly related with weight control [5]. The Body Mass Index (BMI) defines body composition, so TDEE is crucial for good weight control. Both the physical activity level (PAL) and the basal metabolic rate (BMR) affect TDEE [5].

The basal metabolic rate (BMR) is the total calories the body needs for essential activities including nerve circulation, digesting, breathing, temperature control [5]. The process defined in terms of `Physical Activity` is the body movement evoked by the skeletal muscles causing energy consumption [5].

Macronutrients: Macronutrients are the primary components of food that provide energy [5]. There are three main types of macronutrients:

- Protein: Used for muscle repair and growth, as well as supporting other bodily functions [5].
- Carbohydrates: The body's primary source of energy, especially during intense physical activity [5].
- Fats: A backup energy source, important for cell health and hormone regulation [5].

E. Fitness Goals and Energy Requirements

Achieving fitness goals such as cutting, bulking, or body recomposition requires a clear understanding of energy balance and macronutrient needs:

- Caloric Surplus: This occurs when an individual consumes more calories than their Total Daily Energy Expenditure (TDEE) [7]. A surplus is essential for bulking, where the goal is to promote muscle growth by providing the body with sufficient energy and nutrients.
- Caloric Deficit: A deficit is created when an individual consumes fewer calories than their TDEE [7]. This approach is used in cutting, where the aim is to reduce body fat while preserving muscle mass.
- Maintenance Calories: Maintenance refers to the number of calories consumed to match TDEE, resulting in no significant weight change. This is the foundation for body recomposition, where fat loss and muscle gain occur simultaneously through optimized macronutrient distribution [8].

III. METHODOLOGY

A. BMR and TDEE Calculation as System of Linear Equations

a. BMR Calculation

The Mifflin-St. Jeor method for calculating Basal Metabolic Rate (BMR) involves specific equations for males and females.

For males, the BMR is calculated using the formula:

$$\mathbf{BMR = 9.99 \times Weight\ (kg) + 6.25 \times Height\ (cm) - 4.92 \times Age\ (years) + 5}$$

Fig. 6. Equation BMR for Male (Source: [5])

For females, the equation is:

$$\mathbf{BMR = 9.99 \times Weight\ (kg) + 6.25 \times Height\ (cm) - 4.92 \times Age\ (years) - 161} \quad ….[19]$$

Fig. 7. Equation BMR for Female (Source: [5])

b. TDEE Calculation

TDEE multiplies the BMR by an activity factor to consider daily physical activity levels:

$$\mathbf{TDEE = BMR \times PAL}$$

Fig. 8. Equation TDEE (Source: [5])

Physical activities have their levels (PAL): Sedentary or little to no exercise in a day which contains the values 1- 1.2, Less Activity or light exercise 1-3 days/week which contains the values 1.2 – 1.5, High Activity or hard exercise 6-7 days/week contains the values 1.6 – 1.8 and Intensive Activity or very hard exercise contains the values above 1.9 [5].

B. Caloric and Macronutrient Distribution

a. Cutting Phase

In cutting phase, we need a energy deficit, so TDEE in cutting phase is subtracting with 50% of TDEE for maintaining [11]. However, this large reduction can lead to muscle loss. To prevent this, we recommend using 75% of the TDEE for cutting, which helps to minimize muscle loss while still achieving fat reduction. The macronutrient distribution for the cutting phase is as follows.

i. Protein : 30% - 40% of Energy Deficit [9]. Because we use 75% of TDEE so we can get higher percentage like 45% up to 50%.

ii. Carbohydrates : 30–40% to provide energy for workouts[9]. And again because higher TDEE we use 35 % to 40%.

iii. Fats : 20–25% to ensure hormonal balance [12]. Because use higher percentage on TDEE so we can down the

b. Bulking

In Bulking, we need a high of energy surplus so TDEE in bulking we add some of 5%-20% of TDEE for get rates of weight gain of 0.25% - 0.5% of body mass per week [10]. But in this case we use 10% surplus for preventing weight gain fat. So, macronutrient distribution in phase of bulking is.

i. Protein : 25–30% of Energy Sulprus to support muscle growth [7].

ii. Carbohydrates : 40–50% to fuel intense workouts and recovery [7].

iii. Fats : 20–25% to support overall health and hormone production [12].

c. Body Recomposition Phase

In body recomposition, TDEE is not change, because for maintain a certain weight of a body. So, macronutrient distribution in phase of body recomposition is.

i. Protein : 40–45% of TDEE for muscle repair and maintenance [9].

ii. Carbohydrates : 35–40% to support energy needs [7].

iii. Fats : 20–25% to ensure hormonal balance [12].

C. System of Linear Equation Every Phase

a. General Component

i. BMR

BMR=10W+6.25H−5A+k

W: Weight (kg),

H: Height (cm),

A: Age (years),

k: Constanta (male = 5, female = −161).

```python
def calculate_bmr(self, weight, height, age, gender):
    """Calculate Basal Metabolic Rate (BMR) using Mifflin-St Jeor Equation."""
    if gender == "male":
        return 10 * weight + 6.25 * height - 5 * age + 5
    elif gender == "female":
        return 10 * weight + 6.25 * height - 5 * age - 161
```

Fig. 9. BMR Implementation (Source: Primary)

ii. TDEE

TDEE=BMR×PAL

PAL: Physical Activity Level

Sedentary: 1.0−1.2,

Less active: 1.2−1.5,

Active: 1.6−1.8,

Intensive: >1.9.

```python
def calculate_tdee(self, bmr, activity_level):
    """Calculate TDEE based on BMR and activity level"""
    pal_range = self.PAL_RANGES.get(activity_level)
    if not pal_range:
        raise ValueError("Invalid activity level")
    pal = sum(pal_range) / 2
    return bmr * pal
```

Fig. 10. TDEE Implementation (Source: Primary)

b. Cutting Phase

i. TDEE Cutting and Macronutrient Cutting Distribution

```python
if phase == "cutting":
    adjusted_tdee = tdee * 0.75  # 25% deficit
    protein_ratio_lower = 0.45
    protein_ratio_upper = 0.50
    carb_ratio_lower = 0.35
    carb_ratio_upper = 0.40
fat_ratio_lower = 1 - protein_ratio_lower - carb_ratio_lower
fat_ratio_upper = 1 - protein_ratio_upper - carb_ratio_upper
```

Fig. 11. Cutting TDEE and Macronutrient Implementation (Source: Primary)

c. Bulking Phase

i. TDEE Bulkin and Macronutrient Bulking Distribution

```python
elif phase == "bulking":
    adjusted_tdee = tdee * 1.10  # 10% surplus
    protein_ratio_lower = 0.25
    protein_ratio_upper = 0.30
    carb_ratio_lower = 0.40
    carb_ratio_upper = 0.50
fat_ratio_lower = 1 - protein_ratio_lower - carb_ratio_lower
fat_ratio_upper = 1 - protein_ratio_upper - carb_ratio_upper
```

Fig. 12. Bulking TDEE and Macronutrient Implementation (Source: Primary)

d. Body Recomposition Phase

i. TDEE Body Recomposition and Macronutrient Body Recomposition Distribution

```python
else:  # maintenance/recomp
    adjusted_tdee = tdee
    protein_ratio_lower = 0.40
    protein_ratio_upper = 0.45
    carb_ratio_lower = 0.40
    carb_ratio_upper = 0.45
fat_ratio_lower = 1 - protein_ratio_lower - carb_ratio_lower
fat_ratio_upper = 1 - protein_ratio_upper - carb_ratio_upper
```

Fig. 13. Body Recomposition TDEE and Macronutrient Implementation (Source: Primary)

e. Application of System of Linear Equation

i. Matrix of Macronutrition

```python
A = np.array([
    [4, 4, 9],  # Calorie equation
    [1, 0, 0],  # Protein ratio equation
    [0, 1, 0],  # Carb ratio equation
])

B_lower = np.array([
    adjusted_tdee,
    adjusted_tdee * protein_ratio_lower / self.PROTEIN_CAL_PER_GRAM,
    adjusted_tdee * carb_ratio_lower / self.CARB_CAL_PER_GRAM,
])

B_upper = np.array([
    adjusted_tdee,
    adjusted_tdee * protein_ratio_upper / self.PROTEIN_CAL_PER_GRAM,
    adjusted_tdee * carb_ratio_upper / self.CARB_CAL_PER_GRAM,
])
```

Fig. 14. Implementation of matrix Ax=B (Source: primary)

Where it is a Ax=B matrix like fig 1

ii. Solving Matrix with Gauss Elimination

```python
macros_lower = gauss_elimination(A, B_lower)
macros_upper = gauss_elimination(A, B_upper)

protein_grams_lower, carb_grams_lower, fat_grams_lower = macros_lower
protein_grams_upper, carb_grams_upper, fat_grams_upper = macros_upper
```

```python
def gauss_elimination(A, B):
    """Solve a system of linear equations using Gaussian elimination."""
    augmented_matrix = np.hstack((A, B.reshape(-1, 1)))
    rows, cols = augmented_matrix.shape

    for i in range(rows):
        if augmented_matrix[i, i] == 0:
            raise ValueError("Zero pivot encountered.")
        for j in range(i + 1, rows):
            ratio = augmented_matrix[j, i] / augmented_matrix[i, i]
            augmented_matrix[j, i:] -= ratio * augmented_matrix[i, i:]
    solution = np.zeros(rows)
    for i in range(rows - 1, -1, -1):
        solution[i] = (augmented_matrix[i, -1] - np.dot(augmented_matrix[i, :-1], solution)) / augmented_matrix[i, i]
    return solution
```

Fig. 15. Implementation of Gauss Elimination (Source: primary)

D. Simulation

Input :

Weight: 70 kg

Height : 170 cm

Age : 25 years

Gender : male

PAL : high activity

```
=== Nutrition Calculator ===
Enter your weight (kg): 70
Enter your height (cm): 170
Enter your age (years): 25
Enter your gender (male/female): male

Choose your activity level:
  sedentary: Sedentary (very low activity)
  less_active: Less/light Active (light activity)
  high_active: Highly Active (high activity)
  intensive: Very Highly Active (very high activity)

Enter your activity level: high_active
```

Fig. 16. Input Simulation (Source: primary)

Output :

```
Your BMR: 1642 calories
Your TDEE: 2792 calories

Macronutrient distributions for different phases:
--------------------------------------------------

Phase: CUTTING
Adjusted TDEE: 2094 calories
Protein: 235.6g (45.0%) to 261.8g (50.0%)
Carbs: 183.2g (35.0%) to 209.4g (40.0%)
Fat: 46.5g (20.0%) to 23.3g (10.0%)
Total Calories: 2094.0
Solution verified: True

Phase: MAINTENANCE
Adjusted TDEE: 2792 calories
Protein: 279.2g (40.0%) to 314.1g (45.0%)
Carbs: 279.2g (40.0%) to 314.1g (45.0%)
Fat: 62.0g (20.0%) to 31.0g (10.0%)
Total Calories: 2792.0
Solution verified: True

Phase: BULKING
Adjusted TDEE: 3071 calories
Protein: 192.0g (25.0%) to 230.4g (30.0%)
Carbs: 307.1g (40.0%) to 383.9g (50.0%)
Fat: 119.4g (35.0%) to 68.3g (20.0%)
Total Calories: 3071.0
Solution verified: True
```

Fig. 17. Output Simulation (Source: primary)

IV. CONCLUSION

This study shows how linear equations can be used to calculate personalized caloric and macronutrient needs based on specific fitness goals like cutting, bulking, and body recomposition. By combining factors such as BMR and physical activity levels, the model provides a flexible and analytical way to plan nutrition. The results show that using linear equations is a dependable way to estimate macronutrient distribution and caloric needs. This method connects what we learn in nutrition science with real-life use, giving trainers and fitness fans a solid base to create personalized diet plans. Future research might look into how we can use machine learning techniques to improve these models for different populations and various dietary preferences, making them more adaptable and precise.

V. APPENDIX

The complete program of this paper can be found below.
https://github.com/FaqihMSY/Application-System-of-Linear-Equation-to-Analyze-Nutrition-Fitness-Program.git

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

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