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# A MATHEMATICAL MODEL OF OVERWEIGHT/OBESITY IN MOROCCO, USING HUMAN BIOMASS

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***Abstract*- In this study we present a Markov model that illustrates the dynamics of overweight/obesity (in time) by considering four categories: Underweight, Normal weight, Overweight and Obese. Various scenari can be considered by simulation with different parameters values. We propose a long-term strategy that allows a control of the annual transition from one weight category to another with the aim to reduce the proportion of overweight and obese people. This is not a mere mathematical model, pragmmatic results can be obtained in the real life by sensitization to a healthy diet, promotion of physical activity and regular weight control.**

***Keywords*** - Markov model, human biomass, Body Mass, overweight, obesity, strategy

## I. INTRODUCTION

The World Health Organization (WHO) defined Overweight and obesity as "a condition of abnormal or excessive fat accumulation in adipose tissue, to the extent that health may be impaired", meaning that the amount of excess fat in absolute terms, have important health implications[1].

Worldwide, overweight and obesity are increasing at alarming rates. As a disease, obesity diminishes both quality of life and life expectancy, but it is also a common risk factor for other diseases like Cardio Vascular Diseases, arthritis, diabetes and many types of cancer [2].

A recent study showed that among women 50- to 84-years old in England, around one in eight hospital admissions are likely to be attributable to overweight or obesity, translating to around 420,000 extra hospital admissions and two million extra days spent in hospital, annually [3].

A convenient measurement of obesity is given by the Body Mass Index (BMI) which is a simple weight to height ratio ($kg/m^2$). Accordingly, obesity (respectively overweight) in adults is defined as a BMI greater than 30 $kg/m^2$ (respectively BMI greater than 25 $kg/m^2$) while underweight is defined by BMI less than 18.5 $kg/m^2$

The last two decades have seen a dramatic increase in overweight and obesity rates in Morocco, calling health decision makers for urgent and efficient strategy and intervention [4].

Following a paper by Walpole et al. who estimated the adult human biomass worldwide [5], we propose a Markov model that illustrates the dynamics (in time) of both human population and human biomass in Morocco, by considering four compartments: Underweight, Normal weight, Overweight and Obese.

We calculate the biomass in each category as the product of population size by the average body mass, assumed to be 45kg, 65kg, 85kg and 115kg in underweight, normal, overweight and obese category respectively.

## II. THE MATHEMATICAL MODEL

The proposed model is a Markov model defined by the four compartments (Underweight (U), Normal weight (N), Overweight (Ov) and Obesity (Ob)), the probability $P_{ii}$ of staying in the same state i and the probability $P_{ij}$ of transition from the state i to the state j (Fig. 1)

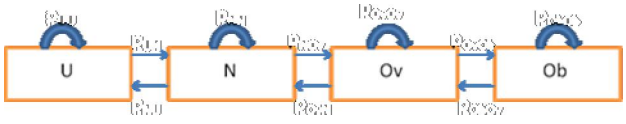


Fig. 1 A compartmental model

Using this model, we seek a strategy to reduce overweight and obesity in 10 years (2015-2025), assuming that we start in 2015 with an initial total adult population $P_0$ of $17x10^6$ individuals, distributed on the 4 compartments as indicated in Table 1 below:

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**Table1:** Population and total body mass in each category (2015) [6]

| | U | N | Ov | Ob | Total |
|---|---|---|---|---|---|
| Population (in million) | 0.66 | 9.93 | 4.59 | 1.82 | 17 |
| % | 3.9 | 58.4 | 27.0 | 10.7 | 100 |
| Total body mass ($10^6$kgs) | 29.83 | 645.32 | 390.5 | 209.1 | 1274.75 |
| % | 2.34 | 50.62 | 30.63 | 16.4 | 100 |

## III. SITUATION AFTER 10 YEARS WITHOUT STRATEGY

If the present trend is maintained (without any strategy of reduction), the yearly dynamics can be summarized by the following transition matrix:

$$P = \begin{pmatrix} 0.0622 & 0.9378 & 0 & 0 \\ 0.0650 & 0.6690 & 0.2660 & 0 \\ 0 & 0.3700 & 0.4300 & 0.2000 \\ 0 & 0 & 0.3650 & 0.6350 \end{pmatrix}$$

Meaning that:

* In the underweight compartment, 6.2 % of the initial Underweight people stay Underweight, while 93.8% become Normal

* In the normal compartment, 6.5% of normal weight become underweight, 67% stay with normal weight and 26.6% become overweight.

* In the overweight compartment, 37% of the initial overweight people become normal weight, 43% stay overweight and 20% become obese

* In the Obese compartment, 36.5% of the initial obese individuals become overweight while 63.5% stay obese.

After 10 years, the total number of adults will reach 20x $10^6$ according to the distribution in Table 2.

**Table2:** Population and total body mass in each category (2025) [6]

| | U | N | Ov | Ob | Total |
|---|---|---|---|---|---|
| Population (in million) | 0.66 | 9.2 | 6.58 | 3.58 | 20 |
| % | 3.3 | 46 | 32.9 | 17.9 | 100 |
| Total body mass ($10^6$kgs) | 29.7 | 598 | 559.3 | 411.7 | 1598.7 |
| % | 1.86 | 37.4 | 35 | 25.75 | 100 |

A Comparison between the percentage of the initial biomass and it's value after 10 years shows a decrease from 2.34% to 1.86% and from 50.62% to 37.4% in underweight and normal states respectively. In opposition, the biomass increases from 30.63% to 35% and from 16.4% to 25.75% in overweight and obese classes respectively.

## IV. TSTRATEGY FOR REDUCTION OF UNDERWEIGHT, OVERWEIGHT AND OBESITY

A strategy is proposed to reduce the proportion of Obese, Overweight, and Underweight adults and to raise the proportion of Normal adults by controlling the annual transition from one weight category to another. For this, we use the transition matrix $P_p$ defined by

$$Pp = \begin{pmatrix} 0.0280 & 0.9720 & 0 & 0 \\ 0.0100 & 0.9700 & 0.0200 & 0 \\ 0 & 0.4500 & 0.2900 & 0.2600 \\ 0 & 0 & 0.9000 & 0.1000 \end{pmatrix}$$

Leading after 10 years of application to the matrix $P_p^{10}$

$$P_p^{10} = \begin{pmatrix} 0.0097 & 0.9381 & 0.0406 & 0.0116 \\ 0.0097 & 0.9376 & 0.0410 & 0.0117 \\ 0.0094 & 0.9220 & 0.0519 & 0.0167 \\ 0.0093 & 0.9136 & 0.0577 & 0.0194 \end{pmatrix}$$

A ten years application of the strategy shows that each of the underweight, overweight, obese classes has decreased while the normal state has risen. More precisely, a comparison between the percentage of the initial biomass and it's value after a 10 years strategy shows a decrease from 2.34% to 0.61% , from 30.63% to 5.81% and from 16.4% to 2.34% in underweight, overweight and obese classes respectively. While the biomass increases nearly twofold from 50% to 91.24% in the normal weight category

**Table 3:** Population and total body mass in each category after 10 years with strategy (2025)

| | U | N | Ov | Ob | Total |
|---|---|---|---|---|---|
| Population (in million) | 0.18 | 18.6 | 0.91 | 0.27 | 20 |
| % | 0.9 | 93 | 4.55 | 1.35 | 100 |
| Total body mass ($10^6$kgs) | 8 | 1209 | 77 | 31 | 1325 |
| % | 0.61 | 91.24 | 5.81 | 2.34 | 100 |

## V. A 25 YEARS STRATEGY: EQUILIBRIUM

If the previous strategy is applied during 25 years, equilibrium will be achieved with the population in normal weight category reaching 93.66% and representing 92.1% of the total biomass while the three other categories are minimized as indicated in Table4 below.

**Table 4:** Population and total body mass in each category after 25 years with strategy (2040)

| | U | N | Ov | Ob | Total |
|---|---|---|---|---|---|
| Population (in million) | 0.24 | 23.4 | 1 | 0.3 | 25 |
| % | 0.96 | 93.66 | 4.17 | 1.2 | 100 |
| Total body mass ($10^6$kgs) | 10.8 | 1521 | 85 | 34.5 | 1651.3 |
| % | 0.65 | 92.1 | 5.15 | 2.1 | 100 |

## VI. DISCUSSION

Of the 57 million deaths that occurred worldwide in 2008, about 36 million (63%) were due to non communicable diseases (NCDS) for which obesity is one of the main risks factors. Eastern Mediterranean countries in general and Morocco in particular, are among the most affected countries by rising prevalence of diabetes and obesity [7-9]
As indicated by the FAO country profiles report, in 1984-85, the average BMI for Moroccan adults was 23 kg/m² and 24% of adults tended to be overweight. The report stressed that obesity was on the rise and that if this trend continues, it may constitute a real public health problem over the next few years [10].

Our model shows that, in absence of strategy, by 2025, half of the Moroccan population will suffer from overweight (33%) and obesity (18%) and this will have disastrous consequences in terms of mortality and multimorbidity caused by non communicable diseases such as cardiovascular diseases, cancer and diabetes[2].
The strategy of controlling the transitions from one weight state to another can be assured in the real life by sensitization to a healthy diet, promotion of physical activity and regular weight control.

According to the last national anthropometric survey, age, level of education, physical inactivity and income are the main social determinants of overweight/obesity. Indeed, obesity is five times higher in the age category [45-59] years (25.7%) than among younger people aged 20 to 24 years (5.2%), and more than twice higher in inactive adults (25.3%) than in active adults (11.2%). Similarly, adults with no education are twice as likely to be obese (21.6%) than adults with higher level of education (10.7%). Finally, regions with higher per capita income/consumption are more affected by obesity (19-22%) than poorer regions (15-16%).

In Morocco, despite more than 3000 km of Mediterranean and Atlantic coasts, the yearly consumption of fish is relatively low (8kg/person/year) compared to nearly 13kg/person/year of poultry and more than 11kg/person/year of red meat. Decision makers should encourage the population to eat more fish and less meat and fat.
Two decades ago, the majority of the Moroccan population was living in rural areas. Nowadays, urbanisation is accelerated and consequently people are eating more fatty and sugary unhealthy diet and having less physical activity as indicated by the WHO report "Promoting physical activity in the Eastern Mediterranean Region through a life-course approach"[11].

## CONCLUSION

Our mathematical model illustrates efficient ways to reduce overweight/obesity in Morocco. A comparison is made between the results yielded under the present trend without action and those expected under a reducing strategy during ten years time, showing that, the first case indicates a decrease from 50.62% to 37.4% in the normal state while the biomass increases from 30.63% to 35% and from 16.4% to 25.75% in overweight and obese classes respectively. In opposition, the second case indicates that the strategy will lead to a decrease from 30.63% to 5.81% and from 16.4% to 2.34% in overweight and obese classes respectively. While the biomass increases nearly twofold from 50% to 91.24% in the normal weight category.

A 25 years strategy leading to equilibrium is also considered and finally, it should be stressed that the model applied here to data from Morocco may be applied to other countries with specific data and other strategies.

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