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## Short Report

# Adolphe Quetelet's Premonition Two Centuries after: Besides Its Implications in Physiology (Obesity, Type 2 Diabetes), Its Paramount Importance in Human Pregnancy

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### ARTICLE INFO

#### Article history:

Received: 24 June, 2020

Accepted: 4 July, 2020

Published: 10 July, 2020

#### Keywords:

*Adolphe Quetelet*

*pregnancy*

*epidemiology*

*pre-pregnancy body mass index*

*gestational weight gain*

*caesarean section*

*obesity*

### ABSTRACT

Adolphe Quételet (1796-1874) proposed in 1835 the "Quételet index", which was re-discovered in 1972 by Keys *et al.* under the acronym "Body Mass index", BMI. The author makes an historical overview of the evolution of this BMI and its interest in medical science and anthropometry. Nowadays this BMI appears to be involved in a mathematical linear law concerning the gestational weight gain in human pregnancies. Getting rid of the current fuzzy recommendations concerning the optimal weight gain for each woman in pregnancy, this may have paramount consequences for the future. When confirmed, Quételet's proposal will appear as a further Copernician revolution in human anthropometry.

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## Introduction

Adolphe Quételet (1796-1874) was born in Ghent (which was at this time part of the new French Republic) from a Frenchman father Augustin Quételet and a Flemish mother Anne Françoise Vandervelde [1]. After his studies in the French-Lycée of Ghent, he received a Doctorate in mathematics in 1819 from the University of Ghent (which became in the meantime part of the Netherlands's kingdom, before becoming Belgium in 1830). In 1823, he went in Paris to meet the French astronomers Alexis Bouvard, François Arago, Pierre-Simon de Laplace, Joseph Fourier and Siméon Denis Poisson [1]. The astronomic French school used at the time the new science of probability and statistics to account for measurements errors around means, using methods of least squares [2, 3]. Quételet thought to apply statistics to social science, coining what he proposed as "social physics". He never was physician, nor did he study medicine, his scientific research encompassed a wide range of disciplines: astronomy, statistics, sociology, demography, meteorology

and history of science. He built and created the astronomical observatory in Brussels where he worked all his life.

For our concern, his most important book was in 1835 *Sur « l'homme et le développement de ses facultés ou Essai de physique sociale »* where he described his concept of the « average man » (« l'homme moyen ») [4]. He presented his theory of human variance around the average. His first main works were on French and Scottish soldiers' mensuration's and their variabilities [3]. His questioning was the relationship between weight and height. During human growth in childhood and adolescence, as a mathematician he speculated that the association/standardization between the height which was linear and weight (which is equivalent to a cubic three-dimensional volume) should be an equation such as  $\text{weight}/\text{height}^3$ . He was completely amazed to notice with his anthropometric data that in fact the body mass in its variations 'behaved' actually as  $\text{weight}/\text{height}^2$ . He proposed then the "Quételet's index" as a cornerstone in studies of body-masses [2]. Nevertheless, during quite all

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the 20<sup>th</sup> century, physicians (and insurance companies) used only the weight/height ratio to evaluate human corpulence and association with morbidities [2, 3].

It was only 137 years after Quételet, in 1972 and with exactly the same pre-supposed mathematical hypothesis ( $w/h^3$ ) that Keys *et al.* also noticed that it was indeed a  $w/h^2$  association [5]. And they proposed the concept of body mass index, BMI. Since then, the BMI became little by little a kind of 'Grail' in all studies on human corpulence-obesity. WHO in 2000 standardized even human bodies' variations as underweight, normal weight, obese only based on BMI [6]. Moreover, now with the so-called obesity epidemics evolving risingly since the 1970's (Nowadays, we witness approximately 1 billion obese,  $\geq 30$  kg/m<sup>2</sup>, out of 7 billion inhabitants on this planet), the BMI became also the later definitions of different obesities (class I to III) [7]. After the Keys' description in 1972, interest for BMI in pregnancies (importantly: the maternal PRE-pregnancy BMI) seemed to appear in the beginning of the 1990's and we have witnessed since then a kind of explosion in terms of association with pregnancy risks [8-12]. There is a strong current ongoing consensus on obesity and consequences for maternal-fetal health, especially for example severe complications such as preeclampsia, not to speak of gestational diabetes mellitus and on the fetal sidal malformations, the risk of stillbirth and fetal overgrowth with as a result increased birthweights (notably the risk of macrosomic babies  $\geq 4$ kg) [13-15].

The major recent findings now is that the corpulence of 2 separate individuals (mother and fetus) have a mutually interactive dependency concerning their respective weight: very thin mothers have a higher risk of small for gestational age (SGA) infants, and rarely give birth to a large for gestational age (LGA) infant. While morbidly obese women often give birth to LGA infants and rarely to SGA. But, it can be counterbalanced by modifications during pregnancy through the maternal gestational weight gain (GWG) [16]. Normal birthweight (AGA) infants (> 10th and < 90th centile of a neonatal population) typically have the lowest perinatal and long-term morbidity. Indeed, We have shown recently in 2018 ago that if we take as principle that the optimal gestational weight in term pregnancies (optGWG) is to have "harmonious babies" for all women whatever their pre-pregnancy Body Mass Index (ppBMI), this is linear curve ( $y=ax+b$ ) [16]. Based on the simple axiom: "what is the optimal gestational weight gain at term (optGWG) to achieve the natural rate of 10% of SGA (small for gestational age) as well as 10% of LGA (Large for gestational age) in newborns in my population", we have found in Reunion island (French overseas Department in the Indian Ocean, nearby Mauritius island) the mathematical linear equation:

$$\text{optGWG (kg)} = -1.2 \text{ ppBMI (Kg/m}^2\text{)} + 42 \pm 2 \text{ kg [16].}$$

When we plot on a graph maternal pre-pregnancy BMI (ppBMI) and the babies' percentiles, 10% SGA-LGA 10% is materialized by a crossing point. The fact that this 10% corresponds to a given maternal BMI category suggests that there is a biological maternal-fetal connection. We proposed to call this crossing point the Maternal-Fetal Corpulence Symbiosis (MFCS) [16]. We had then concluded that the current international recommendations (IOM 2009) for GWG were adequate for normal and over-weighted women but not on the edges: a thin woman (17 kg/m<sup>2</sup>) should gain  $21.6 \pm 2$ kg (instead of 12.5-18) [17]. An obese

32 kg/m<sup>2</sup> should gain 3.6 kg (instead of 5-9). A very obese 40 kg/m<sup>2</sup> should lose 6 kg [16].

Very important, since it is a mathematical linear equation it allows that each woman may be considered as a single plot and that we may calculate for each woman at the beginning of pregnancy her individualized optGWG for that pregnancy. This is of paramount importance because we do not classify women in underweight/normal weight/overweight/obese class I/obese class II. Simply, any health worker may say "you have that BMI at the beginning of pregnancy, it is better to gain (or lose for very obese women) X kilograms". With the rising problem of obesity, one occasion of intense follow-up for a woman is a pregnancy (6 to 10 prenatal visits in 9 months). Knowing since the first prenatal visit which weight gain (or loss) to achieve in 9 months is probably one of the major triggers of a motivation for an overweight/obese woman motivated by the good for her baby. We have put an online calculator consultable on smart phone at REPERE.RE (Reseau Perinatal Reunion), in three languages (French, Spanish and English) for Reunionese women [18].

## Conclusion

Quételet's premonition in 1835 ('mathematization' of anthropometry) and its re-discovery in the last quarter of the 20<sup>th</sup> century should lead to major changes in management of human pregnancies. By looking to achieve in women optimal GWG, we may have a potentially achievable pathway to actively counterbalance the morbid effects of high BMIs.

First, in overweight/obese women, we may have much to win from reducing weight gain during pregnancy: significant health (and cost) benefits by lowering c-section rates, term preeclampsia, macrosomic/LGA babies, and probably gestational diabetes mellitus [19, 20]. Second, and on the other hand, in lean women lower the rates of SGA and low-birthweights babies (< 2500g) [19]. Behaviour taken all along pregnancy (exercises, diet) may induce new habits for the following life in women. It is urgent to verify and establish in all continents (definitions of SGA-LGA are different in different ethnics) the specific linear-curve of optGWG for each geographical area [19]. The implication of BMI in a physiological linear law defining the optimal weight gain in human pregnancy is huge triumph of Quételet's premonition two centuries ago.

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