Bioelectrical Impedance Analysis for Pregnant

Subjects: Obstetrics & Gynaecology | Medicine, General & Internal

Contributor: Aleksandra Obuchowska, Arkadiusz Standyło, Żaneta Kimber-Trojnar, Bożena Leszczyńska-Gorzelak

Pregnancy is a time of significant changes occurring in the composition of a woman's body in order to provide support for the growth and development of the fetus. Bioelectrical impedance analysis (BIA) is used to assess the body composition and hydration status. This technique represents a non-invasive, reliable, and fast clinical approach, which is well tolerated by patients. A segmental impedance measurement might be advantageous in pregnant women, particularly in late pregnancy.

Keywords: bioelectric impedance analysis ; body fat percentage ; obesity ; preeclampsia ; cardiovascular disease risk ; gestational weight gain ; gestational diabetes mellitus

1. Weight Gain in Pregnancy and Gestational Diabetes Mellitus

The BIA method can be successfully used to study the effect of excessive gestational weight gain in pregnancy on the development of obstetric complications. The incidence of excessive gestational weight gain (EGWG) in pregnancy is increasing worldwide and it is associated with complications of pregnancy, including gestational diabetes mellitus (GDM), preeclampsia (PE), preterm labour, foetal macrosomia and obesity in the offspring [1]. GWG is positively associated with the fat mass gain but not fat-free mass. The lean mass (FFM) includes the mass of the total body water (TBW), bone, protein, and non-bone mineral mass. Unfortunately, FM and FFM cannot be divided into the maternal and foetal units by means of this method. In clinical trials, the main goal of the maternal body composition assessment is to evaluate changes in the fat mass (FM) and FFM before, during and after pregnancy [1]. However, a study by Zhang et al. showed that all indicators of BIA (total body water, fat mass, fat-free mass, percent body fat, muscle mass, visceral fat levels, proteins, bone minerals, basal metabolic rate and lean trunk mass), age, weight and BMI were risk factors that significantly increased the occurrence of GDM [2]. In the case of pregnant women, an increase in TBW, FM, FFM, body cell mass (BCM) and extracellular water (ECW) was observed. It is related to the physiological changes taking place during pregnancy, adapting the woman's body to the developing pregnancy and subsequent lactation [3][4]. These changes are progressive and increase as pregnancy continues. From early to late pregnancy, the rate of fat accumulation was comparable [5]. An increase in the fluid retention as well as an increase in the blood volume are both reflective of elevated levels of TBW and ECW [4]. However, during pregnancy, the mean percentage of TBW decreases [5]. Overweight or obese women present significantly lower percentages of TBW. Body fat percentage (BFP), FM and TBW have been observed to be considerably greater in obese women [5]. In healthy women, FM increases during pregnancy despite a slight increase in total energy expenditure and no change is observed in the energy intake [6].

It seems that BIA has a better prognostic potential for gestational and post-partum outcomes than BMI [7][8][9]. With the metric system, the formula for BMI is weight in kilograms divided by height in meters squared. However, Asian individuals have more body fat than Caucasians with the same BMI values [10][11]. Additionally, it is known that the correlation between BMI and body fat content is age and gender dependent. BMI is a crude marker for general fat, and cannot distinguish between the fat and lean body masses [12][13]. In the case of women with a high content of the muscle tissue, BMI does not fulfil its function properly. BMI, along with gestational weight gain, inform about the real nutritional status in pregnancy, however, these parameters do not provide information regarding the distribution of fat [9]. The body fat composition, on the other hand, can be assessed in detail with the use of BIA. Recently, the fat and free-fat masses are known to be more accurate predictors of the maternal nutritional status than BMI [9]. The studies have shown that obesity and EGWG are associated with more frequent adverse maternal and neonatal complications (**Table 1**) [7][14][15][16].

Table 1. Obesity and excessive gestational weight gain—the risk of development of the diseases for the mother and her offspring.

Early Risk	Long-Term Risk	
Mother	gestational diabetes mellitus	diabetes mellitus type 2
	gestational hypertension and preeclampsia	cardiovascular diseases
	caesarean delivery and vacuum/forceps delivery	
Offspring	prematurity	cardiovascular diseases
	macrosomia	obesity
	Intensive Neonatal Care Unit admission after delivery	hypertension
	lower Apgar score	insulin resistance and diabetes mellitus type 2

Higher rates of newborns with a low Apgar score have been observed in obese women compared to women with normal BMI [16][17]. The studies showed that babies born to obese women had an increased risk of admission to the Intensive Care Unit for newborns and their birth weight was above 4000 g [16][18]. The BFP is considered to be a stronger predictor of GDM than BMI [16]. The mean BFP varies significantly during pregnancy [5].

A study by Zhang et al. revealed that bone minerals in early pregnancy were a significant risk factor for GDM [2]. Pathological changes in the maternal TBW detected by means of BIA measurements have been related to gestational maladaptation [19]. It is worth noting that the BIA measurements must be interpreted considering the background of adequate reference values for the population of interest as both bioelectrical properties and their relationship to the body composition are affected by the height, weight, hydration status and stage of life of individual women [19][20].

The amount and composition of a healthy GWG varies greatly among women who are underweight, normal weight, overweight and obese [21]. Studying the mother's body composition and correlating it with her energy balance could facilitate the development of dietary recommendations for women that would help to ensure adequate weight gain during pregnancy. Obesity is a major risk factor for cardiovascular disease [22]. In the studies by Piuri et al. it has been shown that women with hypertensive disorders caused by overweight and obesity had increased TBW and ECW already in early pregnancy [4]. In contrast, women who delivered Small-for-Gestational-Age (SGA) newborns, especially when associated with foetal growth restriction, were more likely to have lower TBW and ECW values [4]. However, the studies were conducted on a small number of women.

EGWG and GDM can have an important effect on the foetal development, which is manifested by an increased predisposition to obesity, insulin resistance, diabetes, hypertension and other diseases in the later life of the offspring. The "foetal programming" hypothesis suggests that adverse effects early in the development lead to permanent changes in the structure, physiology and metabolism of the foetus [23][24][25][26]. These processes make the offspring vulnerable to obesity and related diseases such as diabetes mellitus type 2 (T2DM), hypertension, cardiovascular disease and others throughout their lives, from childhood to adulthood [23][24][27]. These adverse effects are especially noticeable in the presence of maternal nutritional imbalance and metabolic disorders during pregnancy as well as redox dysregulation in the mother–placenta–foetus unit [24].

GDM causes both short- and long-term complications for mothers and foetuses, so it is important to identify the risk factors as early as possible and implement appropriate measures to prevent their development.

Liu et al. investigated a relationship between the body composition measured by BIA at 13 weeks of gestation and GDM diagnosed at 24–28 weeks of gestation [28]. They observed that in those pregnant women whose fat mass percentage (FMP) was above 28% the risk of developing GDM was higher than in the women who presented with normal FMP. In Wang's studies, the percentage of body fat was the strongest risk factor for GDM after adjusting the BMI before pregnancy [29]. On the other hand, the skeletal muscle mass percentage (SMMP) was inversely related to the increased risk of developing GDM [28]. The fat mass index (FMI) in early pregnancy has been shown to be a predictor of GDM. FMI may be an indicator of the effectiveness of an intervention to reduce the risk of GDM [28]. In Balani's research, the visceral fat mass (VFM) was found to influence the development of GDM [30]. Maternal hyperglycaemia may also be a risk factor for foetal programming, as it has been shown to reduce both foetal glucose tolerance and insulin sensitivity [24].

2. Gestational Hypertension and Preeclampsia

BIA is also used as one of the additional tests in assessing the risk of developing GH and PE [22][31][32][33]. PE is a serious disease diagnosed in 2–8% of pregnancies [34][35], and it is associated with the risk of preterm labour. For this reason, it is

important that the risk of PE occurrence should be identified as soon as possible and appropriate treatment and care methods should be immediately initiated. It has been shown that BIA assessment in conjunction with other tests (e.g., haemodynamics) can be used to identify early markers of an impaired cardiovascular adaptation and body composition that may lead to complications in the third trimester of pregnancy [31]. According to several study reports, women with PE gained significantly more weight during pregnancy than women with normal blood pressure [36][37]. Maternal obesity prior to pregnancy is one of the most significant risk factors for PE [38]. A relationship has been observed between the pre-pregnancy BMI value and likelihood of PE occurrence [38][39]. Nonetheless, the use of BMI in pregnancy is very limited and the results are unreliable. BIA is an alternative method of assessing overweight and obesity on the basis of the amount of body fat. In 2015, Sween et al. investigated a relationship between the content of adipose tissue in obese women in the first trimester of pregnancy and the occurrence of PE in those mothers-to-be [40]. It was shown that an increase in the adipose tissue content increased the risk of developing PE. It was also found that body fat correlated more strongly with the risk of PE than BMI. There is a viewpoint that adipose tissue is involved in the pathophysiology of PE because obesity is related, inter alia, to oxidative stress (OS). In the case of normalised and overweight women, no correlation was observed between the increase in both BMI and adipose tissue content and the increased risk of developing PE [40].

75% of PE patients had excessive GWG [41]. The Da Silva study showed that TBW and ECW were higher in the group of women with PE, while in both absolute and relative terms the percentage of ICW was lower in this group [3][32]. In the study of Staelens, the ECW/ICW ratio is higher in preeclamptic patients compared to uncomplicated pregnancies and GH, and ICW does not differ between the groups [3].

In the study of McLennan et al., attention was drawn to the early postpartum period in women who developed PE [42]. The study found that six months after pre-eclampsia, the women presented significantly higher body weight, higher percentage of fat mass, much higher BMI as well as higher insulin resistance (HOMA-IR) and reduced HDL levels in comparison to the women with normal blood pressure during pregnancy. It was observed that women who were diagnosed with PE during pregnancy led a less active lifestyle after delivery in comparison to the women who did not develop PE [42]. However, this may be related to the higher percentage of caesarean sections in this group, which is usually associated with decreased activity after delivery [42][43]. Breastfeeding had no significant effect on total or activity-related energy expenditure in both normal blood pressure and PE groups. Women with a history of PE consumed an average of 13% less kilojoules than women with normal blood pressure during pregnancy. However, the composition of macronutrients in the diets of women from both groups was similar [42].

Meta-analyses revealed a two- to three-times higher risk of chronic cardiovascular disease and T2DM in women after PE compared to women with normotension during pregnancy [44][45][46][47].

Levario-Carrillo et al. investigated body composition in four groups of patients: women with uncomplicated pregnancy, women with GH, women with mild PE and women with severe PE [48]. It was observed that maternal body composition differed significantly in the patients with hypertensive complications during pregnancy. In the patients diagnosed with elevated blood pressure, a higher pre-pregnancy BMI was observed. 66% of women diagnosed with GH, 78% with mild PE and 70% with severe PE had increased total body water (above the 90th percentile). In all the studied groups, patients presenting with co-morbid oedema showed increased TBW. It is suggested that these data may be related to a possible inadequate water volume distribution due to the alteration in capillary permeability [48].

In a study by Yeboah et al., maternal serum leptin and lipid profile were analysed, also, body fat percentage was determined during the first trimester [49]. The study subjects were purposively selected. The authors tried to determine whether in the first trimester of pregnancy, the serum concentration of leptin and the body fat percentage (%BF) are altered in those pregnant women who subsequently develop PE, and whether these changes are significant enough to enable determining which pregnant women are likely to develop PE. The use of BIA measurements made it possible to determine %BF, whereas such obesity indicators as BMI, waist circumference, waist-to-height ratio and waste-to-hip ratio cannot determine the percentage of body fat. The study of Yeboah et al. showed that significantly higher leptin levels existed in those women who subsequently developed PE in comparison to their counterparts. Moreover, it was indicated that obese women are at a greater risk of developing PE during the course of pregnancy, which corroborates earlier studies reporting a link between obesity and an increased risk of developing PE [49].

References

1. Most, J.; Marlatt, K.L.; Altazan, A.D.; Redman, L.M. Advances in assessing body composition during pregnancy. Eur. J. Clin. Nutr. 2018, 72, 645–656.

2. Zhang, R.Y.; Wang, L.; Zhou, W.; Zhong, Q.M.; Tong, C.; Zhang, T.; Han, T.L.; Wang, L.R.; Fan, X.; Zhao, Y.; et al. Measuring Maternal Body Composition by Biomedical Impedance Can Predict Risk for Gestational Diabetes Mellitus: A Retrospective Study among 22,223 Women. J. Matern. Fetal Neonatal Med. 2020, 28, 1–8.
3. Staelens, A.S.; Vonck, S.; Molenberghs, G.; Malbrain, M.L.N.G.; Gyselaers, W. Maternal Body Fluid Composition in Uncomplicated Pregnancies and Preeclampsia: A Bioelectrical Impedance Analysis. Eur. J. Obstet. Gynecol. Reprod. Biol. 2016, 204, 69–73.
4. Piuri, G.; Ferrazzi, E.; Bulfoni, C.; Mastricci, L.; Di Martino, D.; Speciani, A.F. Longitudinal Changes and Correlations of Bioimpedance and Anthropometric Measurements in Pregnancy: Simple Possible Bed-Side Tools to Assess Pregnancy Evolution. J. Matern. Fetal Neonatal Med. 2017, 30, 2824–2830.
5. Bai, M.; Susic, D.; O'Sullivan, A.J.; Henry, A. Reproducibility of Bioelectrical Impedance Analysis in Pregnancy and the Association of Body Composition with the Risk of Gestational Diabetes: A Substudy of MUMS Cohort. J. Obes. 2020, 2020, 3128767.
6. Abeysekera, M.V.; Morris, J.A.; Davis, G.K.; O'Sullivan, A.J. Alterations in energy homeostasis to favour adipose tissue gain: A longitudinal study in healthy pregnant women. Aust. N. Z. J. Obstet. Gynaecol. 2015, 56, 42–48.
7. Trojnar, M.; Patro-Małysza, J.; Kimber-Trojnar, Ż.; Czuba, M.; Mosiewicz, J.; Leszczyńska-Gorzelak, B. Vaspin in Serum and Urine of Post-Partum Women with Excessive Gestational Weight Gain. Medicina 2019, 55, 76.
8. Kimber-Trojnar, Ż.; Patro-Małysza, J.; Skórzyńska-Dziduszko, K.E.; Oleszczuk, J.; Trojnar, M.; Mierzyński, R.; Leszczyńska-Gorzelak, B. Ghrelin in Serum and Urine of Post-Partum Women with Gestational Diabetes Mellitus. Int. J. Mol. Sci. 2018, 19, 3001.
9. Wang, Y.; Mao, J.; Wang, W.; Qiou, J.; Yang, L.; Chen, S. Maternal fat free mass during pregnancy is associated with birth weight. Reprod. Health. 2017, 14, 47.
10. Deurenberg, P.; Bhaskaran, K.; Lian, P.L.K. Singaporean Chinese adolescents have more subcutaneous adipose tissue than Dutch Caucasians of the same age and body mass index. Asia Pac. J. Clin. Nutr. 2003, 12, 261–265.
11. Gallagher, D.; Heymsfield, S.B.; Heo, M.; A Jebb, S.; Murgatroyd, P.R.; Sakamoto, Y. Healthy percentage body fat ranges: An approach for developing guidelines based on body mass index. Am. J. Clin. Nutr. 2000, 72, 694–701.
12. Wells, J.C.K.; Fewtrell, M.S. Measuring Body Composition. Arch. Dis. Child. 2006, 91, 612–617.
13. Vitale, S.G.; Corrado, F.; Caruso, S.; Di Benedetto, A.; Giunta, L.; Cianci, A.; D'Anna, R. Myo-inositol supplementation to prevent gestational diabetes in overweight non-obese women: Bioelectrical impedance analysis, metabolic aspects, obstetric and neonatal outcomes—A randomized and open-label, placebo-controlled clinical trial. Int. J. Food Sci. Nutr. 2020, 1–10.
14. Kimber-Trojnar, Ż.; Patro-Małysza, J.; Trojnar, M.; Darmochwał-Kolarz, D.; Oleszczuk, J.; Leszczyńska-Gorzelak, B. Umbilical Cord SFRP5 Levels of Term Newborns in Relation to Normal and Excessive Gestational Weight Gain. Int. J. Mol. Sci. 2019, 20, 595.
15. Kimber-Trojnar, Ż.; Patro-Małysza, J.; Trojnar, M.; Skórzyńska-Dziduszko, K.E.; Bartosiewicz, J.; Oleszczuk, J.; Leszczyńska-Gorzelak, B. Fatty Acid-Binding Protein 4—An "Inauspiciou" Adipokine—In Serum and Urine of Post-Partum Women with Excessive Gestational Weight Gain and Gestational Diabetes Mellitus. J. Clin. Med. 2018, 7, 505.
16. Zhao, Y.-N.; Li, Q.; Li, Y.-C. Effects of body mass index and body fat percentage on gestational complications and outcomes. J. Obstet. Gynaecol. Res. 2013, 40, 705–710.
17. Briese, V.; Voigt, M.; Wisser, J.; Borchardt, U.; Straube, S. Risks of pregnancy and birth in obese primiparous women: An analysis of German perinatal statistics. Arch. Gynecol. Obstet. 2010, 283, 249–253.
18. Henson, M.C.; Castracane, V.D. Leptin in Pregnancy. Biol. Reprod. 2000, 63, 1219–1228.
19. Berlit, S.; Tuschy, B.; Stojakowits, M.; Weiss, C.; Leweling, H.; Sütterlin, M.; Kehl, S. Bioelectrical impedance analysis in pregnancy: Reference ranges. In Vivo 2013, 27, 851–854.
20. Berlit, S.; Stojakowits, M.; Tuschy, B.; Weiss, C.; Leweling, H.; Sütterlin, M.; Kehl, S. Bioelectrical impedance analysis in the assessment of pre-eclampsia. Arch. Gynecol. Obstet. 2014, 291, 31–38.
21. Bosaeus, M.; Andersson-Hall, U.; Andersson, L.; Karlsson, T.; Ellegård, L.; Holmäng, A. Body Composition during Pregnancy: Longitudinal Changes and Method Comparisons. Reprod. Sci. 2020, 27, 1477–1489.
22. Vonck, S.; Lanssens, D.; Staelens, A.S.; Tomsin, K.; Oben, J.; Bruckers, L.; Gyselaers, W. Obesity in Pregnancy Causes a Volume Overload in Third Trimester. Eur. J. Clin. Investig. 2019, 49, e13173.
23. Kwon, E.J.; Kim, Y.J. What is fetal programming?: A lifetime health is under the control of in utero health. Obstet. Gynecol. Sci. 2017, 60, 506–519.

24. Kopp, W. How Western Diet And Lifestyle Drive The Pandemic Of Obesity And Civilization Diseases. Diabetes Metab. Syndr. Obes. Targets Ther. 2019, 12, 2221–2236.

25. Kopp, W. Development of Obesity: The Driver and the Passenger. Diabetes Metab. Syndr. Obes. 2020, 13, 4631–4642.

26. Marciniak, A.; Patro-Małysza, J.; Kimber-Trojnar, Ż.; Marciniak, B.; Oleszczuk, J.; Leszczyńska-Gorzelak, B. Fetal Programming of the Metabolic Syndrome. Taiwan J. Obstet. Gynecol. 2017, 56, 133–138.

27. Paknahad, Z.; Fallah, A.; Moravejolahkami, A.R. Maternal Dietary Patterns and Their Association with Pregnancy Outcomes. Clin. Nutr. Res. 2019, 8, 64–73.

28. Liu, Y.; Liu, J.; Gao, Y.; Zheng, D.; Pan, W.; Nie, M.; Ma, L. The Body Composition in Early Pregnancy is Associated with the Risk of Development of Gestational Diabetes Mellitus Late During the Second Trimester. Diabetes Metab. Syndr. Obes. 2020, 13, 2367–2374.

29. Wang, Y.; Luo, B.R. The Association of Body Composition with the Risk of Gestational Diabetes Mellitus in Chinese Pregnant Women: A Case-Control Study. Medicine 2019, 98, 17576.

30. Balani, J.; Hyer, S.; Johnson, A.; Shehata, H. The importance of visceral fat mass in obese pregnant women and relation with pregnancy outcomes. Obstet. Med. 2013, 7, 22–25.

31. Gagliardi, G.; Tiralongo, G.M.; LoPresti, D.; Pisani, I.; Farsetti, D.; Vasapollo, B.; Novelli, G.P.; Andreoli, A.; Valensise, H. Screening for Pre-Eclampsia in the First Trimester: Role of Maternal Hemodynamics and Bioimpedance in Non-Obese Patients. Ultrasound Obstet. Gynecol. 2017, 50, 584–588.

32. Da Silva, E.G.; Carvalhaes, M.A.; Hirakawa, H.S.; Da Silva, E.G.; Peraçoli, J.C. Bioimpedance in Pregnant Women with Preeclampsia. Hypertens. Pregnancy 2010, 29, 357–365.

33. Gyselaers, W.; Vonck, S.; Staelens, A.S.; Lanssens, D.; Tomsin, K.; Oben, J.; Dreesen, P.; Bruckers, L. Gestational hypertensive disorders show unique patterns of circulatory deterioration with ongoing pregnancy. Am. J. Physiol. Integr. Comp. Physiol. 2019, 316, R210–R221.

34. Ingec, M.; Borekci, B.; Kadanali, S. Elevated Plasma Homocysteine Concentrations in Severe Preeclampsia and Eclampsia. Tohoku J. Exp. Med. 2005, 206, 225–231.

35. Mol, B.W.J.; Roberts, C.T.; Thangaratinam, S.; Magee, L.A.; de Groot, C.J.M.; Hofmeyr, G.J. Pre-Eclampsia. Lancet 2016, 387, 999–1011.

36. Hillesund, E.R.; Seland, S.; Bere, E.; Sagedal, L.R.; Torstveit, M.K.; Lohne-Seiler, H.; Vistad, I.; Øverby, N.C. Preeclampsia and gestational weight gain in the Norwegian Fit for Delivery trial. BMC Res. Notes 2018, 11, 1–6.

37. Shao, Y.; Qiu, J.; Huang, H.; Mao, B.; Dai, W.; He, X.; Cui, H.; Lin, X.; Lv, L.; Wang, D.; et al. Pre-pregnancy BMI, gestational weight gain and risk of preeclampsia: A birth cohort study in Lanzhou, China. BMC Pregnancy Childbirth 2017, 17, 1–8.

38. Bodnar, L.M.; Catov, J.M.; Klebanoff, M.A.; Ness, R.B.; Roberts, J.M. Prepregnancy Body Mass Index and the Occurrence of Severe Hypertensive Disorders of Pregnancy. Epidemiology 2007, 18, 234–239.

39. Bodnar, L.M.; Ness, R.B.; Markovic, N.; Roberts, J.M. The Risk of Preeclampsia Rises with Increasing Prepregnancy Body Mass Index. Ann. Epidemiol. 2005, 15, 475–482.

40. Sween, L.K.; Althouse, A.D.; Roberts, J.M. Early-Pregnancy Percent Body Fat in Relation to Preeclampsia Risk in Obese Women. Am. J. Obstet. Gynecol. 2015, 212, 841–847.

41. Chung, Y.J.; Kim, E.Y. Usefulness of bioelectrical impedance analysis and ECW ratio as a guidance for fluid management in critically ill patients after operation. Sci. Rep. 2021, 11, 1–10.

42. McLennan, S.L.; Henry, A.; Roberts, L.M.; Siritharan, S.S.; Ojurovic, M.; Yao, A.; Davis, G.K.; Mangos, G.; Pettit, F.; Brown, M.A.; et al. Maternal adiposity and energy balance after normotensive and preeclamptic pregnancies. J. Clin. Endocrinol. Metab. 2021.

43. Kim, J.-I.; Lee, K.-J. Bladder Symptoms, Fatigue and Physical Activity in Postpartum Women. Asian Nurs. Res. 2017, 11, 50–55.

44. Wu, P.; Haththotuwa, R.; Kwok, C.S.; Babu, A.; Kotronias, R.A.; Rushton, C.; Zaman, A.; Fryer, A.A.; Kadam, U.; Chew-Graham, C.A.; et al. Preeclampsia and Future Cardiovascular Health. Circ. Cardiovasc. Qual. Outcomes 2017, 10, e003497.

45. Bellamy, L.; Casas, J.P.; Hingorani, A.D.; Williams, D.J. Pre-Eclampsia and Risk of Cardiovascular Disease and Cancer in Later Life: Systematic Review and Meta-Analysis. BMJ 2007, 335, 974.

46. McDonald, S.D.; Malinowski, A.; Zhou, Q.; Yusuf, S.; Devereaux, P.J. Cardiovascular Sequelae of Preeclampsia/Eclampsia: A Systematic Review and Meta-Analyses. Am. Heart J. 2008, 156, 918–930.

47. Brown, M.C.; Best, K.; Pearce, M.; Waugh, J.; Robson, S.C.; Bell, R. Cardiovascular disease risk in women with pre-eclampsia: Systematic review and meta-analysis. Eur. J. Epidemiol. 2013, 28, 1–19.
48. Levario-Carrillo, M.; Avitia, M.; Tufiño-Olivares, E.; Trevizo, E.; Corral-Terrazas, M.; Reza-López, S. Body Composition of Patients with Hypertensive Complications During Pregnancy. Hypertens. Pregnancy 2006, 25, 259–269.
49. Yeboah, F.A.; Ngala, R.A.; Bawah, A.T.; Asare-Anane, H.; Alidu, H.; Hamid, A.W.M.; Wumbee, J.D.K. Adiposity and Hyperleptinemia during the First Trimester among Pregnant Women with Preeclampsia. Int. J. Womens Health 2017, 9, 449.