Response to Reviewer 3 Comments

Point 1: Summary

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The authors present their work on simulating 3D shape of pregnant and post-partum women. The authors collected data of women's anthropometric measurements in different gestational stages and post-partum. Based on the work of a previous study, they include the pregnancy data to learn a model to predict a woman's body shape at specific pregnancy and post-partum stages, based on her pre-pregnancy measurements. The authors have created a web-app to display their model, allowing women to input their metrics and observe a simulation. The website was positively received by pregnant women. The simulation looks interesting.

Response 1: We are thankful to the reviewer for encouragement and insightful comments to improve our manuscript.

Issues

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Point 2: 1. The motivation of the work is not solid.

- The authors make claims that are not backed by citations, e.g.

"Currently, obesity is increasing rapidly causing health issues, especially in pregnant women.",

"If a woman in the post-partum period is unable to regulate her weight to her pre-pregnant weight within six months, she will increase her BMI until becoming obese."

Response 2: We thank the reviewer for this viewpoint. The sentences that explain our motivation are updated with the citations as follows:

"Obesity during pregnancy is a serious health problem for women. Worldwide, obstetricians and midwives have confronted increasing obesity among pregnant women [1, 2]."

[1] Poston, L., Harthoorn, L., van der Beek, E. et al. Obesity in Pregnancy: Implications for the Mother and Lifelong Health of the Child. A Consensus Statement. Pediatr Res 69, 175–180 (2011). DOI: 10.1203/PDR.0b013e3182055ede

[2] Chen C, Xu X, Yan Y. Estimated global overweight and obesity burden in pregnant women based on panel data model. PLoS One. 2018 Aug 9;13(8):e0202183. DOI: 10.1371/journal.pone.0202183.

“It was reported that if a woman in the postpartum period was unable to regulate her weight to her pre-pregnant weight within six months, postpartum weight retention could predict future weight gain and long-term obesity [10]. Another study suggested that the BMI of a woman of more than six months postpartum would indicate the retaining extra body fluids produced during pregnancy, as well as extra fat during the first six months postpartum [11].”

[10] van der Pligt P, Willcox J, Hesketh KD, Ball K, Wilkinson S, Crawford D, Campbell K. Systematic review of lifestyle interventions to limit postpartum weight retention: implications for future opportunities to prevent maternal overweight and obesity following childbirth. Obes Rev. 2013 Oct;14(10):792-805. DOI: 10.1111/obr.12053.

[11] Arizona WIC (Women Infant and Children) Nutrition Care Guidelines: Breastfeeding and Postpartum Women, 2015. Available online at: https://azdhs.gov/documents/prevention/azwic/face-to-face/2015/jan/6-Breastfeeding-and-Postpartum-Women.pdf

Point 3: In their introduction they say this simulation model is necessary to

"raise awareness among women as a measure to prevent being overweight", however, this seems to be the opinion of the authors because they do not provide previous research suggesting this need nor do the authors carry out a study to demonstrate this.

Response 3: We thank the reviewer for this comment. We have updated the introduction with clearer statements with references as follows:

“Sui Z et al. reported a statistically significant indication that women with a high degree of body image dissatisfaction were more likely to have higher gestational weight gain [12]. Hill B et al. also reported that timing of pregnancy and body attitudes could predict gestational weight gain (GWG). The findings suggested that lower attractiveness in early-to-middle pregnancy was associated with higher GWG [13]. Therefore, in this work, the 3D body shape simulation of women before, during, and after pregnancy has been developed with an expectation that women will not misestimate their BMI to prevent being overweight during pregnancy and the postpartum period. 3D body simulation may encourage women to prevent overweight behaviours before and throughout pregnancy to maintain good health in the long run."

References:

[12] Sui Z., Turnbull D., Dodd J. Effect of body image on gestational weight gain in overweight and obese women. Women and Birth. Volume 26, Issue 4, December 2013, Pages 267-272. DOI: 10.1016/j.wombi.2013.07.001

[13] Hill B, Skouteris H, McCabe M, Fuller-Tyszkiewicz M. Body image and gestational weight gain: a prospective study. J Midwifery Womens Health. 2013 Mar-Apr;58(2):189-94. doi: 10.1111/j.1542-2011.2012.00227

Point 4: The authors write:

"There is no physical simulation or any way to find the shape proportion of pregnant and postpartum women", of course, there are ways of obtaining this proportion, the most basic being measuring the people with a measuring tape.

Response 4: We have revised the sentence and given an explanation with references.

Nevertheless, there is no physical simulation for the shape proportion of pregnant and postpartum woman subjects as they are a population group with vulnerability to use the 3D body scanner for data collection. The word "vulnerable" is in the context of human research protections. Pregnant women are considered vulnerable because of the involvement of the fetus that may be affected by the research and the fetus cannot give consent [17].

"It was not possible to collect the body shape data using the 3D body scanner in the study. This is because most pregnant women are concerned about the safety of 3D body scanners and have questions about the scanner potential consequences at all stages of pregnancy [18]. It is difficult to obtain an approval for applications for research projects involving human subjects from the Institutional Review Board (IRB), and especially when asking for consent forms for research subjects [17]. We also needed pregnant and postpartum women to measure their own body circumferences at home every four weeks during pregnancy and postpartum.

References:

[17] Pregnant Women, Fetuses and Neonates as Vulnerable Population. Human Research Protection Program, 2009. Available online at https://cphs.berkeley.edu/policies_procedures/sc501.pdf

[18] Pregnancy and Security Screening. Frequently Asked Questions in HPS Specialists in Radiation Protection, 2016. Available online at https://hps.org/publicinformation/ate/faqs/pregnancyandsecurityscreening.html

Point 5: As a motivation of what differentiates their work from others (e.g. [7,8]), the authors claim that "our 3D simulation has clothing, face, hair and can add texture." It is unclear how are these features relevant for a body shape simulation.

Response 5: Thank you for pointing this out to us. We have revised the paragraph to be:

"Body Visualizer has used the dataset based on SizeUSA, American and European Surface Anthropometry Resource (CAESAR) as the basis for creating 3D body shapes visualization [28, 29]. It is a visualization tool for a parametric 3D body model that provides metrically

accurate anthropomorphic measurements based on laser scans of thousands of people from different ethnicities. However, it is still lacking the 3D body models for pregnant and postpartum women especially for Asian women. Therefore, in this study we focused on simulating the 3D shape of pregnant and postpartum women for Thais."

[28] Loper, M., Mahmood, N., Romero, J., Pons-Moll, G., & Black, M. J. (2015). SMPL: A skinned multi-person linear model. ACM transactions on graphics (TOG), 34(6), 1-16.

[29] Osman, A. A., Bolkart, T., & Black, M. J. (2020). Star: Sparse trained articulated human body regressor. In Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part VI 16 (pp. 598-613). Springer International Publishing

Point 6: "The simulation of the body shape can raise an awareness of women and encourage them to prevent overweight behaviours before and throughout the pregnancy to maintain good health in the long run." This is a major claim, however, the authors do not present any evidence on this.

In their conclusion, they write for the first time that their model is meant as an alternative to body scanning. This is perhaps a better motivation, however, it requires to be backed by literature.

Response 6: Thank you for suggesting a better motivation. We have revised the sentence as follows:

"The simulation of the body shape from body measurements can be considered as a low-cost alternative to full-body 3D scanning [32]."

Reference:

[32] Gallucci A., Znamenskiy D., and Petkovic M. Prediction of 3D Body Parts from Face Shape and Anthropometric Measurements. Journal of Image and Graphics, Vol. 8, No. 3, September 2020. DOI: 10.18178/joig.8.3.67-74

Point 7: 2. There are missing citations and incorrect citations:

"Then data were analysed and processed in simulation of 3D modelling of pregnant and postpartum women based on data of normal female shapes from SizeThailand." There is no reference to SizeThailand.

Response 7: Thank you for your advice. We have added references to SizeThailand as follows:

Then data were analyzed and processed to create simulation of 3D modeling of pregnant and postpartum women based on data of non-pregnant female shapes from SizeThailand [19, 20].

References

[19] Wells, J., Treleaven, P. & Charoensiriwath, S. Body shape by 3-D photonic scanning in Thai and UK adults: comparison of national sizing surveys. Int J Obes 36, 148–154 (2012). DOI: 10.1038/ijo.2011.51

[20] Wells JC, Charoensiriwath S, Treleaven P. Reproduction, aging, and body shape by three-dimensional photonic scanning in Thai men and women. Am J Hum Biol. 2011 May-Jun;23(3):291-8. DOI: 10.1002/ajhb.21151.

Point 8: The name "Z-Size Ladies v.1" is mentioned often but no citation is provided.

Response 8: We updated the manuscript by removing v.1, v.2 and left with only Z-Size Ladies and referred to reference [31].

Reference

[31] Z-Size Ladies: Web Application for BMI Timeline & Program assesses ladies' sizes and facial images. 2021. Available at: https://zsize.openservice.in.th/

Point 9: Their explanation of the work of Michael J. Black in multiple citations [5-11] is wrong:

"However, Body Visualizer has been using "Civilian American and European Surface Anthropometry Resource" (CAESAR) as the basis for creating Body Visualizer, which based on the data from SizeUSA while the result of the simulation is just a clay figure." Just a clay figure? I suggest the authors to look at the following papers:

Loper, M., Mahmood, N., Romero, J., Pons-Moll, G., & Black, M. J. (2015). SMPL: A skinned multi-person linear model. ACM transactions on graphics (TOG), 34(6), 1-16.

Osman, A. A., Bolkart, T., & Black, M. J. (2020). Star: Sparse trained articulated human body regressor. In Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part VI 16 (pp. 598-613). Springer International Publishing

The body visualizer is just a visualization tool for a parametric 3D body model that provides metrically accurate anthropomorphic measurements based on laser scans of thousands of people from different ethnicities.

Response 9: We thank the reviewer for the suggestion of references. We have revised the paragraph and included references as follows (as mentioned above):

"Body Visualizer has used the dataset based on SizeUSA, American and European Surface Anthropometry Resource (CAESAR) as the basis for creating 3D body shapes visualization [28, 29]. It is a visualization tool for a parametric 3D body model that provides metrically accurate anthropomorphic measurements based on laser scans of thousands of people from different ethnicities. However, it is still lacking the 3D body models for pregnant and postpartum women especially for Asian women. Therefore, in this study we focused on simulating the 3D shape of pregnant and postpartum women for Thais."

[28] Loper, M., Mahmood, N., Romero, J., Pons-Moll, G., & Black, M. J. (2015). SMPL: A skinned multi-person linear model. ACM transactions on graphics (TOG), 34(6), 1-16.

[29] Osman, A. A., Bolkart, T., & Black, M. J. (2020). Star: Sparse trained articulated human body regressor. In Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part VI 16 (pp. 598-613). Springer International Publishing

Point 10: There are relevant studies on prediction of 3D body shape during pregnancy. I suggest the authors also have a look at this paper for example:

Balasubramanian, M., & Robinette, K. (2020). Longitudinal anthropometric changes of pregnant women: dynamics and prediction. International Journal of Fashion Design, Technology and Education, 13(3), 231-237.

Response 10: Thank you for your advice. We have added a sentence related to the study that the reviewer suggested as follows:

"There are some relevant studies on prediction of 3D body shape during pregnancy using multiple 3D body scans with a purpose of setting the standard sizing chart for maternity wear that addresses the changes throughout pregnancy [33]."

[33] Balasubramanian, M., & Robinette, K. (2020). Longitudinal anthropometric changes of pregnant women: dynamics and prediction. International Journal of Fashion Design, Technology and Education, 13(3), 231-237.

3. Unclear methodology

Point 11: "3D body shape simulation of normal women, pregnant and postpartum women shape with body proportions are predicted in real-time and online from weight, height and gestational age." What do you mean by 'predicted in real-time'?

Response 11: Thank you for your question. We have added the explanation about 'predicted in real-time' as follows:

"A real-time prediction in our study is a service that provides the predictions via an HTTP call to simulate the 3D shape of pregnant and post-partum women via the web browser after the users input their data."

Point 12: The authors say they collected anthropomorphic data in a 6 months time span, however it is not clear how or who collected the data (was there a specialist measuring the women, did they do self-measurements, etc.) Were these repeated measurements? Were the same participants measured in time?

Response 12: Thank the reviewer for pointing this out. We have explained more about our methodology in the manuscript as follows:

"For the data collection, it started at 12-16 weeks of pregnancy and 0 weeks of postpartum. The research assistant measured body circumferences of chest, waist, hip, thighs (left/right), and upper arms (left/right) and explained to the volunteers how to measure their body size by themselves. The measurement was delicated considering that the interrater held the measuring tape in the correct position and not too tight.

The measurement values could vary approximately +/- 2 cm. The measurements were taken at home by pregnant/postpartum women subjects with the assistance of someone at home. The measurement was carried every 4 weeks. There would be a reminder notice from the research assistant when the schedule was approaching. Three measurements were taken 3 at each position and the median value was recorded for each position. The volunteers sent their measured data to the research team via mobile LINE application each time they measured their body shape."

Point 13: "All analysed data were 587 datasets, including 94 women who were 12-week gestation; 98 of 16-week gestation; 91 of 20-week gestation; 82 of 24-week gestation; 79 of 28-week gestation; 78 of 32-week gestation and 65 of 36-week gestation" This information is hard to understand.

Response 13: Thank you for your comment. We have revised this paragraph as follows:

"The data from 98 pregnant women volunteers were collected and analyzed. Information of all pregnant volunteers is shown in Table 1. The data were 587 sets in total. Each data contained woman's age, pre-pregnancy weight, height, gestational age, weight gain during pregnancy, inseam (measure once at 12–16 week pregnancy), and body circumference measurements: chest, waist, hip, upper arm (left/right), and thigh (left/right). The data used for this study were from 94 women who were 12-week gestation; 98 of 16-week gestation; 91 of 20-week gestation; 82 of 24-week gestation; 79 of 28-week gestation; 78 of 32-week gestation and 65 of 36-week gestation, a total of 587 sets."

Point 14: In order to create the 'pregnant body shape' the authors utilize a combination of the following 'bodies': "Details of creating a 3D normal female shape by combining thin, big breast, big waist, big hip, tall and long legs avatars". It is unclear why this choice was made, or what supports making such a mix of 'attributes'/'3D body shapes'.

Response 14: To clarify the reviewer's comments regarding the creation of the pregnant body shape, we have explained more in the manuscript as follows:

"The idea of utilizing a combination of the avatar bodies for 3D shape simulation came from the morphing technique [50]. Morphing is a geometric interpolation technique, which has to mix different characteristics of the objects. The body shape simulation by adjusting only a specific part was a challenge. For example, chest or hip circumference can be set bigger or smaller with the least impact on the waist and others. Therefore, our team designed the avatars in different ways to combine the shape of the body and the users are able to adjust the size of specific parts as needed. Therefore, the 3D non-pregnant female shape was created by combining thin, big breast, big waist, big hip, tall and long legs avatars using the morphing technique to make it easier to adjust only specific part of the body."

Reference

[50] Kang J.Y., Lee B.S., Application of morphing technique with mesh-merging in rapid hull form generation, International Journal of Naval Architecture and Ocean Engineering, Volume 4, Issue 3, 2012, Pages 228-240, DOI: 10.2478/IJNAOE-2013-0092.

Point 15: On page 6, the authors write: "From the experiment, it was found that the K0 - K5 values were also proportional to the body mass index (BMI) and also depended on the gestational age as well." Here, for the first time, a 'experiment' is mentioned but there is no explanation of it in the paper.

Response 15: To clarify the reviewer's comment, we have explained more in the manuscript as follows:

"The simulation of non-pregnant body shape from our previous study [42], showed that the variables K_1- K_5 depended upon the BMI values. Therefore, a similar experiment was performed in this study by testing on 30 pregnant female subjects whose 3D data were simulated using equation 2 in comparison with the statical measurement from equation 1."

In our experiment, the K0-K5 values are the sum between K00-K05 and the corresponding between Alp0-Alp5 shown in equations (3):

The values of Chest, Waist, Hip, and Inseam which are the values that defined K00-K05 were calculated from non-pregnant female body shape according to the article by Sinthanayothin et al. [42] which can be expressed by linear equations shown in equation (4).

From our experiments of cross-sectioning and measuring the circumference of 3D simulation figures, the Alp0 – Alp5 were functions of the BMI which could be calculated as the following morphing equations. The quadratic functions derived from second-order polynomial regression and parameters from the experiment were performed to obtain a 3D pregnant woman model that was the closest to the calculated statistical value as shown in equation (5).

[42]: Sinthanayothin C, Bholsithi W, Gansawat D, et al. Simulation of three-dimensional female body shapes with proportional representation for various weights and heights. SIMULATION. 2020;96(11):851-866. DOI:10.1177/0037549720944466

Point 16: Multiple equations contain constant values (e.g. equation 3), however, the rationale behind these constants is not explained in the paper.

Response 16: Regarding the constant values in equation 3, 13 values came from non-pregnant women simulation. Because the simulation of pregnant and postpartum women is modified based on the nonpregnant / non-postpartum female from the previous study.

Therefore, we have explained about all of the constants in equation 3 in the manuscript as follows:

"The simulations of pregnant and postpartum women were further modified based on data from non-pregnant female from our previous study [42]. The constant values of equation 3 were derived from the size of the designed avatars as mentioned in [42]. "The thin avatar was used as a default or initial model with the minimum values of chest, waist, and hip of approximately 57, 40, and 68 cm, respectively. The avatar with the big breast was applied to adjust the size of the chest values. The chest circumference of the avatar with the big breast was set as maximum chest values of approximately 200 cm. Similarly, for the avatar with the large waist and with the big hip, the size of the waist and hip of these avatars were set as maximum values of approximately 160 and 180 cm, respectively. For inseam, the default value for the thin avatar was approximately 73 cm. In this work, the minimum and maximum values of the inseam have been set to 48 and 120 cm, respectively. The last avatar (tall avatar) with the height of 200 cm is set to be the maximum height value."

[42]: "Sinthanayothin C, Bholsithi W, Gansawat D, et al. Simulation of three-dimensional female body shapes with proportional representation for various weights and heights. SIMULATION. 2020;96(11):851-866. DOI:10.1177/0037549720944466"

Point 17: Authors make a differentiation in four categories of BMI:

"The 3D simulation of pregnant women can simulate at various gestational ages for women with four types of pre-pregnancy BMI: Underweight (BMI <18.5), Normal weight 256 (18.5 ≤ BMI ≤ 24.9), Overweight (25.0 ≤ BMI ≤ 29.9) and Obese (BMI ≥ 30.0)"

However, to my understanding, there is no factor in the equations to account for these categories. Why is this differentiation being made?

Response 17: We have explained more about the differentiation in four categories of BMI in Section 3.2 as follows:

Although there is no direct factor of BMI categories in our correlation analysis, the body proportions, chest, waist, hip, thigh, and upper arm circumferences were calculated using multiple linear regression method based on 587 data collected from 98 pregnant women. However, when a user wanted to predict her 3D pregnancy shape at other gestation ages using the web app (Z-Size Ladies), weight gain during pregnancy was unknown. Therefore, weight gain during pregnancy (Wg) would be predicted from pre-pregnancy BMI as shown in Table 2 based on the Institute of Medicine (IOM), 2009 [46].

[46]: Institute of Medicine, US.; National Research Council, US. Summary. In Weight Gain During Pregnancy: Reexamining the Guidelines., 1st ed.; Rasmussen, K.M., Yaktine, A.L., Eds.; National Academies Press: Washington D.C., USA, November 2009; DOI: 10.17226/12584, pp. S-2.

We also explained in the Discussion as follows:

Different types of pre-pregnancy BMI indicates the differences in weight gain during pregnancy. Therefore, 3D simulation of pregnant women was simulated at various gestational ages for women with four types of pre-pregnancy BMI according to IOM 2009 [46].

Point 18: "The data of 83 postpartum women volunteers were collected and analysed". Are these some of the women who were part of the pregnancy group?

Response 18: The data of 83 postpartum women volunteers that were collected and analyzed, were from a completely different group from the pregnancy group. In addition, the volunteers (75 pregnant and 74 postpartum women) for testing the simulation application were also a new group.

Point 19: "The postpartum weight Wppt was predicted from the review articles". Why not from observations in your post-pregnancy group?

Response 19: Thank you for your comment, we have explained more about the postpartum weight Wppt in the manuscript as follows:

“The postpartum weight (Wpp) from measurement was already used as an independent variable in calculating the body circumference of postpartum women according to Equation

7. However, when a user wants to predict her 3D postpartum shape at other postpartum weeks using web app (Z-Size Ladies), postpartum weight is unknown. In the case of calculating the postpartum weight as a dependent variable, it would be complicated since it involved many factors such as BMI, pre-pregnancy weight, gestational weight gain, baby weight, and postpartum age. Moreover, data must be divided into 4 groups according to BMI types (underweight, normal weight, overweight and obese). Therefore, data from 83 postpartum women must also be divided into 4 groups, resulting in less than 30 postpartum women in each group. Data with $n < 30$ may not be sufficient for statistical analysis calculations [51].

Therefore, in the postpartum simulation application, the postpartum weight (Wpp) was predicted from the review articles."

[51] Sharma A. Is n = 30 really enough? A popular inductive fallacy among data analysts. 2020. Available online at: https://towardsdatascience.com/is-n-30-really-enough-a-popular-inductive-fallacy-among-data-analysts-95661669dd98

Point 20: The accuracy is reported by means of correlation coefficients, it would be in my opinion clearer to report also absolute errors, and in general a more thorough analysis would be helpful.

Response 20: Following the reviewer's suggestion, we have added the relative error (percentage of absolute error) in the accuracy reported in the manuscript.

Point 21: The 'satisfaction' test is fine, however, at the beginning of the paper, the authors claim that their simulation will: (1) raise awareness in women, (2) encourage women to prevent overweight before and during pregnancy, (3) maintain long term health. None of these outcomes have been measured, thus, making it not possible to evaluate the actual success of the study (if these points are really the goal of the study).

Response 21: We agree with the reviewer. Therefore, we revised our objectives to 1. Develop a simulation tool of 3D body shape for pregnant and postpartum women; 2. Test the accuracy of the developed body simulation tool. We revised the objectives in the manuscript as follows:

"Application Z-Size Ladies [31] described in this paper was intended to collect user data in the form of BMI timeline and simulate the 3D female body shape for non-pregnant, pregnant women, and postpartum women. Z-Size Ladies application [31] is a tool that helps pregnant and postpartum women to simulate their 3D-body shapes. The aim of developing the Z-Size Ladies application is to be a tool that can create a precise online 3D model for non-pregnant, pregnant, and postpartum women in real-time with a simple set of input data of their weight, height, and gestational age. The tool was validated by several linear regression studies and

users survey. The simulation of the body shape from body measurements can be considered as a low-cost alternative to full-body 3D scanning [32].”

References:

[31] Z-Size Ladies: Web Application for BMI Timeline & Program assesses ladies’ sizes and facial images. 2021. Available at: https://zsize.openservice.in.th/

[32] Gallucci A., Znamenskiy D., and Petkovic M. Prediction of 3D Body Parts from Face Shape and Anthropometric Measurements. Journal of Image and Graphics, Vol. 8, No. 3, September 2020. DOI: 10.18178/joig.8.3.67-74

5. Wording

Point 22: The term "normal women" to describe women who are not pregnant or in the "post-partum" period is problematic.

Response 22: We have revised the word ‘normal women’ to ‘non-pregnant women’ throughout the manuscript.

Point 23: The authors use the word "datasets" throughout their manuscript, in a way that I assume means just data or data points. e.g. "They used datasets from 25 pregnant Caucasian ladies". This should be revisited and corrected.

Response 23: We have revised the word ‘datasets’ to ‘data’ throughout the manuscript.

Point 24: In equation 6, gestational age is represented by the variable 'NV' but earlier in the paper (e.g. equation 1) it is represented by the variable Wkp.

Response 24: We have revised the variable ‘NV’ in equation 6 to ‘Wkp’.

Point 25: A general major issue is the lack of clarity in the general writing, structure and flow of the paper. It is difficult to fully follow the logic of the authors.

Response 25: We thank the reviewer again for your insightful review of our work. We have revised the manuscript accordingly to the reviewer's suggestions with more details and support references. We hope that the revised manuscript is clearer and easier to follow.