Comparison between American Institute of Medicine Guidelines and Local Recommendation for Gestational Weight Gain in Taiwanese Primiparous Women

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Research article

Abstract

Background : American Institute of Medicine (IOM) recommends different ranges of gestational weight gain (GWG) based on pre-pregnancy body mass index (BMI). In Taiwan, IOM guidelines are implemented concurrently with the local recommendation for GWG (10–14 kg). This study compared between the two sets of guidelines in relation to adverse perinatal outcomes.

Methods : We analyzed 31653 primiparas with singletons from 2011-2016 annual National Breastfeeding Surveys. Logistic regressions for preterm birth, small for gestational age (SGA), large for gestational age (LGA), cesarean section and excessive postpartum weight retention (PWR) were fitted separately for GWG categorized according to IOM and Taiwan ranges. Areas under the receiver-operator curves (AUC) and the predicted probabilities for each outcome were compared in each BMI group.

Results : AUC for both guidelines ranged within 0.51 – 0.73. Compared to Taiwan recommendation, IOM ranges showed lower probabilities of SGA for underweight (0.11–0.15 versus 0.14–0.18), of LGA for obese (0.12–0.15 versus 0.15–0.18), of excessive PWR for overweight (0.19–0.30 versus 0.27–0.39), and obese (0.15–0.22 versus 0.25-0.36); and higher probabilities of excessive PWR for underweight (0.17-0.33 versus 0.14-0.22).

Conclusions : Discriminative performance of IOM and Taiwan recommendations was poor for the five adverse birth outcomes, and no preference for either set of recommendations could be inferred from our results. In the absence of specific GWG guidelines, health care workers may provide inconsistent information to their patients. Future research is needed to explore optimal GWG ranges that can reliably predict locally relevant perinatal outcomes for mother and child.

Introduction

Many women and health providers are concerned with the question how much weight should be gained during pregnancy [1]. Gaining too much or not enough weight may affect maternal and child health during pregnancy, at delivery, and later in life, including increasing risks of obesity, cardiovascular diseases, and diabetes for mothers and their children [2]. The recommendations for GWG have changed dramatically over the past century [1]. The recent guidelines were developed by the American Institute of Medicine (IOM) in response to the obesity epidemic [2]. Based on the comprehensive literature review, optimal ranges for GWG were defined for each category of pre-pregnancy body mass index (BMI): 12.5–18 kg for BMI < 18.5; 11.5–16 kg for 18.5 ≤ BMI < 25; 7–11.5 kg for 25 ≤ BMI < 30; and 5–9 kg for BMI ≥ 30 [2]. The women with GWG above the IOM recommendations had higher risks of cesarean section and excessive postpartum weight retention (PWR) (i.e., retaining more than 5 kg at 1 year postpartum). The infants born to those women could be at increased risk for presenting as large for gestational age (LGA), macrosomia, and childhood obesity. Women with GWG below the recommended ranges had higher risks of preterm birth, having a small for gestational age (SGA) baby, and failure to initiate breastfeeding [2,3]. Population-based

survey revealed that only 32% of American mothers with full-term singletons were within the recommended range in 2010–2011 [4].

There is no global consensus about optimal GWG ranges. Recent review [5] found that only 14 out of 70 developing and developed countries had some recommendations for GWG. Canada and Finland adopted IOM guidelines, while New Zealand adjusted IOM guidelines with different BMI cutoffs for its Caucasian (18.5, 25, 30 kg/m^2), Asian (18.5, 23, 27.5 kg/m^2) and Pacific (18.5, 26, 32 kg/m^2) populations. Recommendations in other countries varied widely and were supported by limited evidence. Among the few countries in Asia with GWG recommendations, only Vietnam and Japan introduced BMI-specific ranges [5].

Recommended GWG range in Taiwan was defined as 10–14 kg, and IOM guidelines were added to the maternal health book, published by Taiwan Health Promotion Administration (HPA) in 2017 [6]. Following World Health Organization (WHO) suggestion to develop local BMI cutoffs in Asian populations [7], BMI cutoffs in Taiwan were set to 18.5, 24, and 27 to differentiate between underweight, normal, overweight, and obese [8]. So far, only few Taiwanese scholars examined GWG in relation to maternal and child health outcomes with controversial results, whereas some studies provided certain support for IOM guidelines [9-11], some found IOM guidelines inappropriate for Taiwanese women [12]. Despite the existence of evidence-based BMI categorization for the local population [13], Taiwanese studies mostly employed western BMI cutoffs, which may have resulted in misclassification bias. So far, none of the Taiwanese studies have used their data to compare between IOM and local GWG guidelines.

The objective of our study was to compare IOM and Taiwan GWG guidelines in a representative sample of Taiwanese women using receiver-operator curves and predicted probabilities for maternal and child adverse outcomes proposed by IOM in the latest revision of GWG guidelines: preterm birth, cesarean section, SGA, LGA, and excessive PWR [2]. Assessing discriminative performance of both guidelines is expected to provide an initial step in accumulating evidence for the development of local GWG guidelines in Taiwan.

Methods

Study design and participants

We used the 2011-2016 data from National Breastfeeding Surveys commissioned annually by Taiwan HPA. Detailed description of data collection was published earlier [14]. Structured questionnaires were delivered at 6-14 months postpartum to randomly selected mothers, who gave birth in those years. Primiparous mothers with singletons were included in the current study. Observations with missing data

were excluded (n=3 471). After applying inclusion/exclusion criteria, we obtained the sample of 31 653 primiparas with singletons, of whom 20.5% were underweight, 67.6% had normal pre-pregnancy BMI, 8.3% were overweight and 4.8% were obese (Figure 1).

Measurements

The dependent variables in our study included preterm birth, SGA, LGA, cesarean section, and excessive PWR based on the IOM review: [2]. Preterm birth was defined as delivery at less than 37 gestational weeks. SGA and LGA were defined as infant birth weight less than the 10th percentile or more than the 90th percentile, respectively, adjusted for gestational week and infant sex. The percentiles were obtained from Taiwan national intrauterine growth charts for live-born singletons delivered between 22 and 42 weeks [15]. Cesarean section was confirmed through the survey questions: 1) was the delivery natural or cesarean? 2) was there a medical indication for cesarean section? Since non-medical indications accounted for less than 2% of all cesarean sections, and sensitivity analysis without these cases did not affect our results, we included all cesarean sections in the final analysis. Excessive PWR was calculated by subtracting pre-pregnancy weight from the current weight reported in the interview and was defined as ≥ 5 kg [2]. Although women in our sample were interviewed at 6 to 14 months postpartum, there was no significant difference in the proportion of excessive PWR among the postpartum months (χ^2 test p=0.354).

Pre-pregnancy BMI was calculated from self-reported weight and height and categorized with Taiwanese cutoffs as underweight (BMI<18.5), normal (18.5≤BMI <24) , overweight (24≤BMI <27), and obese (BMI≥27) [8]. Inadequate, appropriate, and excessive GWG was categorized according to IOM guidelines (12.5-18 kg for BMI<18.5, 11.5-16 kg for 18.5≤BMI<25, 7-11.5 kg for 25≤BMI<30, 5-9 kg for BMI≥30) [2], and according to Taiwan HPA recommendation of 10-14 kg regardless of pre-pregnancy BMI [6].

We selected maternal age, education, country of origin, employment, infant sex, year of birth, and health status at birth as potential confounding variables in statistical models, based on literature review[16-18] and significant associations between these variables and our dependent variables.

Statistical analysis

Mean and standard deviation of GWG were calculated for each BMI group, and analysis of variance with least significant difference between pair-wise means was adjusted using Bonferroni's correction for multiple testing. All other variables were cross-tabulated by BMI status, and χ^2 tests were performed to compare the proportions among the BMI groups.

Two logistic regression models were fit for each of the five outcomes (preterm delivery, cesarean section, SGA, LGA, and excessive PWR). The independent variable of GWG was categorized according to the IOM in one model and according to the Taiwan GWG recommendation (10–14 kg) in the other model. Both models were adjusted for maternal age, education, country of origin, employment, infant sex, health status at birth, and year of birth. We estimated discriminative performance of IOM and Taiwan GWG

categorizations with receiver-operator curves for each logistic regression by calculating area under the curve (AUC). Discrimination was considered poor if AUC estimate was between 0.5 and 0.7 and acceptable if AUC was 0.7 or higher [19]. Comparison between AUC for IOM and Taiwan GWG categorizations was based on p-values for Wald statistics [20]. The above statistical procedure was performed for the total sample size and for each BMI group. Odds ratios and 95% confidence intervals (CI) are presented in the supplementary materials (Supplementary Table S1).

We also fitted adjusted logistic regression models for each BMI group with GWG as a continuous variable in order to calculate the predicted probabilities with 95% CI for each of the five outcomes (Supplementary Tables S2-S6). Predicted probabilities and 95% CI were plotted against GWG within the range of 4–20 kg. Overlapping CI suggested non-significant differences between IOM and Taiwan GWG ranges.

Level of significance was set to a two-sided α=0.05 in all statistical procedures. The missing values comprised 9.9% of the analytical sample. A sensitivity analysis, with 100 multiple imputations by chained equations [21], did not alter our findings and conclusions; therefore, we present initial results after case-wise deletion. All the analyses were performed with Stata Statistical Software: Release 15 (Stata Corp. 2017. College Station, TX: Stata Corp LLC).

Results

Mean GWG did not differ significantly between the underweight (14.1±5.0) and normal BMI groups (14.2±5.0); however, it was significantly lower in the overweight (13.1± 5.8) and the obese (11.2±6.4 kg) groups. The underweight group showed the highest proportion of SGA (15.2% versus 8.8–10.8%), while the obese group showed the highest proportion of preterm birth (9.7% versus 5.9–7.1%), LGA (17.1% versus 4.3–12.4%), and caesarean section (50.2% versus 28.3–40.5%). The highest percentage of excessive PWR (37.5% versus 24.4–30.6%) was observed in the overweight group. Underweight group tended to be younger than 29, while obese group tended to be 35 or older, and the age group of 30-34 had the highest percentage of women with normal BMI (44.9% versus 39.0–42.1%). Pre-pregnancy BMI also differed significantly (p<0.001) by education, employment, country of origin, and newborn health status at birth (Table 1).

GWG status differed significantly (χ^2 test p<0.001) between BMI groups within both IOM and Taiwan categorizations. Percentages of appropriate GWG according to IOM ranged between 33.3% in the obese and 40.5% in the underweight, which were similar to the values obtained based on Taiwan GWG categorization: 33.6% in the obese and 41.7% in the underweight. IOM categorization showed higher percentages of inadequate GWG in the underweight (41.9%) and excessive GWG in the obese (50.2%) compared to the percentages obtained from Taiwan categorization (15.8% and 27.8%, respectively). Within the normal BMI group, a greater proportion of mothers were categorized as having excessive GWG according to the Taiwan recommendation (44.2% versus 29.0%), while the IOM categorization revealed a higher percentage (30.9% versus 15.3%) of inadequate GWG (Figure 2).

Preterm birth

Both GWG categorizations showed AUC<0.70 for preterm birth. Taiwan categorization showed significantly (p<0.001) higher AUC in the total study sample (0.64 versus 0.63) and in the underweight group (0.61 versus 0.57) (Table 2).

Predicted probability of preterm birth decreased with each additional kilogram of GWG, from 0.10 at 4 kg to 0.04 at 20 kg, for the normal BMI group. No significant differences were observed among the underweight, normal, and overweight groups. Within the obese group, those who gained more than 13 kg had a significantly higher probability (0.09) of preterm birth than the other BMI groups (Figure 3A).

IOM and Taiwan GWG ranges showed overlapping probabilities of preterm birth in the normal, overweight, and obese groups. A slightly significant variation between the IOM and Taiwan ranges was observed in the underweight BMI group, with preterm birth probabilities ranging from 0.06 (95% CI: 0.06−0.07) to 0.04 (95% CI: 0.03−0.04) within the IOM range (12.5−18 kg) and from 0.08 (95% CI: 0.07−0.08) to 0.05 (95% CI: 0.05−0.06) within the Taiwan range (10−14 kg) (Figure 3A, Supplementary Table S2).

Small for gestational age

Both GWG categorizations showed AUC<0.60 for SGA. IOM categorization showed significantly (p<0.010) higher AUC in the total study sample (0.59 versus 0.58) (Table 2).

Predicted probability of SGA decreased with each additional kilogram of GWG from 0.17 at 4 kg to 0.08 at 20 kg for normal BMI. No significant differences were observed between the overweight and obese groups. The group with normal BMI displayed significantly higher probabilities of SGA (≥0.12) than the overweight (≥0.10) and obese groups (≥0.08) if less than 12 kg were gained during gestation. Underweight, who gained less than 18kg had significantly higher probability of SGA (≥0.11) than the normal (≥0.09), overweight (≥0.08) and obese (≥0.07) groups (Figure 3B).

Probabilities of SGA overlapped for IOM and Taiwan GWG ranges in the normal, overweight and obese groups. A significant variation between IOM and Taiwan ranges was observed in the underweight BMI group, with SGA probabilities ranging from 0.15 (95% CI: 0.14−0.16) to 0.11 (95% CI: 0.10−0.12) within the IOM range (12.5−18 kg) and from 0.18 (95% CI: 0.17−0.20) to 0.14 (95% CI: 0.13−0.15) within the Taiwan range (10−14 kg) (Figure 3B, Supplementary Table S3).

Large for gestational age

Both GWG categorizations showed AUC<0.70 for LGA. IOM categorization showed significantly higher AUC in the total study sample (0.65 versus 0.62, p<0.001) and in the normal BMI group (0.60 versus 0.59, p=0.008) (Table 2).

Predicted probability of LGA increased with each additional kilogram of GWG, from 0.03 at 4 kg to 0.10 at 20 kg, for the normal BMI group. The underweight group had significantly lower probability (0.01 − 0.07)

within the range of 4–20 kg, while the overweight (0.08–0.15) and obese (0.12–0.24) groups had significantly higher probabilities than the normal BMI groups (0.03–0.10) (Figure 3C).

Probabilities of LGA overlapped for IOM and Taiwan GWG ranges in the underweight, normal, and overweight groups. A slightly significant variation between the IOM and Taiwan ranges was observed in the obese BMI group, with LGA probabilities ranging from 0.12 (95% CI: 0.10–0.15) to 0.15 (95% CI: 0.13–0.17) within the IOM range (5–9 kg) and from 0.15 (95% CI: 0.13–0.17) to 0.18 (95% CI: 0.16–0.21) within the Taiwan range (10–14 kg) (Figure 3C, Supplementary Table S4).

Cesarean section

IOM categorization showed significantly (p<0.010) higher AUC for cesarean section in the total study sample (0.73 versus 0.72), whereas AUC estimates in BMI groups did not exceed 0.55 and did not differ between IOM and Taiwan GWG categorizations (Table 2).

Predicted probability of cesarean section increased with each additional kilogram of GWG, from 0.26 at 4 kg to 0.36 at 20 kg, for the normal BMI group. The underweight group had significantly lower probability (0.22–0.32) of cesarean section within the range of 4–20 kg, while the overweight group (0.35–0.47) and obese (0.45–0.54) group had significantly higher probabilities of cesarean section than the normal BMI group (0.26-0.36) (Figure 3D).

Probabilities of cesarean section overlapped for IOM and Taiwan GWG ranges in the underweight, normal, and overweight groups. A slightly significant variation between the IOM and the Taiwan ranges was observed in the obese group, with probabilities for cesarean section ranging from 0.46 (95% CI: 0.42–0.59) to 0.48 (95% CI: 0.45–0.51) within the IOM range (5–9 kg), and from 0.49 (95% CI: 0.46–0.51) to 0.51 (95% CI: 0.48–0.54) within the Taiwan range (10–14 kg) (Figure 3D, Supplementary Table S5).

Excessive postpartum weight retention

IOM categorization showed significantly higher AUC for excessive PWR in the total study sample (0.69 versus 0.68, p<0.001) and in the normal BMI group (0.67 versus 0.66, p<0.001). AUC for Taiwan categorization were significantly higher in the overweight (0.69 vs 0.67, p0.026) and in obese (0.70 vs 0.67, p=0.001) groups (Table 2).

Predicted probability of excessive PWR increased with each additional kilogram of GWG, from 0.08 at 4 kg to 0.49 at 20 kg, for the normal BMI group. The underweight group had significantly lower probability (≥0.09) than the normal BMI group, if more than 7 kg were gained during gestation. The overweight (0.13–0.61) and obese (0.13–0.55) groups displayed significantly higher probabilities than the normal BMI group (0.08–0.49); however, there was no significant difference between the overweight and obese groups (Figure 3E).

Significant differences between the predicted probabilities for excessive PWR between IOM and Taiwan ranges were observed in all BMI groups. The probabilities in the underweight group ranged from 0.17

(95% CI: 0.16−0.19) to 0.33 (95% CI: 0.31−0.34) within the IOM range (12.5−18 kg) and from 0.14 (95% CI: 0.12−0.15) to 0.22 (95% CI: 0.21−0.23) within the Taiwan range (10−14 kg). The probabilities in the normal BMI group ranged from 0.20 (95% CI: 0.19−0.20) to 0.34 (95% CI: 0.33−0.35) within the IOM range (11.5−16 kg) and from 0.17 (95% CI: 0.17−0.18) to 0.28 (95% CI 0.27−0.28) within the Taiwan range (10−14 kg). The probabilities in the overweight BMI group ranged from 0.19 (95% CI: 0.16−0.21) to 0.30 (95% CI: 0.27−0.32) within the IOM range (7−11.5 kg) and from 0.27 (95% CI: 0.24−0.29) to 0.39 (95% CI: 0.27−0.42) within the Taiwan range (10-14 kg). The probabilities in the obese group ranged from 0.15 (95% CI: 0.12−0.17) to 0.22 (95% CI: 0.20−0.25) within the IOM range (5−9 kg), and from 0.25 (95% CI: 0.22−0.27) to 0.36 (95% CI: 0.33−0.39) within the Taiwan range (10−14 kg) (Figure 3E, Supplementary Table S6).

Discussion

To date, this study is the first to compare the Taiwan and the IOM guidelines for GWG in a large national sample of primiparas with singletons. The recommended range of GWG in Taiwan categorized more obese as gaining inadequate weight (38.6%) and more underweight as gaining excessive weight (42.5%), while IOM ranges categorized more underweight as gaining inadequate weight (41.9%) and more obese as gaining excessive weight (50.2%) (Figure 2). This discrepancy in GWG categorization is likely due to the fact that the IOM ranges are BMI-specific, which were established to address the obesity epidemic in the United States [2]. While obesity is a global issue, the BMI distribution in Asian countries is different compared to the BMI distribution in the West [7]. Along with the increasing prevalence of women entering pregnancy with an excessive BMI, there is also a high proportion of women who are underweight at the beginning of gestation, as we observed in our previous study based on a nationally representative sample of Taiwanese women (under review, data not shown). High prevalence of underweight women that do not gain an adequate amount of weight during pregnancy has been reported in Taiwan, Korea, and Japan [16,17,22,23]. The BMI-specific ranges of GWG recommended by IOM appear to tackle this issue more effectively, compared to the GWG range recommended by Taiwan HPA, by categorizing a greater proportion of underweight women as having inadequate GWG.

Although there were significant, albeit small, differences in AUC between IOM and Taiwan categorizations in the total study sample, often there were no significant differences between both GWG categorizations within the BMI groups. Taiwan guidelines were slightly better at discriminating the prevalence of preterm birth in the underweight group (AUC 0.61 versus 0.57), and excessive PWR in the overweight (AUC 0.69 versus 0.67) and obese (AUC 0.70 versus 0.67) groups. Nevertheless, the discriminative performance of both classification systems was rather poor, as indicated by AUC ≤0.70 for the four adverse outcomes, and only 0.72 − 0.73 for cesarean section in the total study sample (Table 2). Previously, a Japanese study reported AUC of 0.61 and 0.62 for SGA and LGA, respectively [17]. Another study in Latin-American women similarly showed poor discriminative performance (AUC<0.70) of weekly BMI gain during pregnancy for low birth weight, SGA and LGA [24]. Most recent and comprehensive meta-analysis of 25 cohort studies also showed low ability of IOM categorization to distinguish between women with and

without perinatal adverse outcomes, with AUC ranging from 0.55 to 0.60 for preterm birth, SGA, LGA, and cesarean section [25]. The multifactorial nature of the adverse birth outcomes, as well as unmeasured confounding, could contribute to low estimates of AUC. Another possible reason for low AUC estimates may stem from the fact that our study population included respondents to breastfeeding surveys. Since adverse birth outcomes could hamper breastfeeding [26], mothers who did not breastfeed may have experienced some of the birth outcomes of interest in our study and chose not to participate. However, previous studies that assessed the general population of pregnancies unrelated to breastfeeding yielded similar results [17,24,25].

Based on the predictive probabilities of the adverse birth outcomes, the recommended GWG range of 10–14 kg in Taiwan was more protective for overweight and obese women regarding preterm birth and SGA, as well as for women in the underweight and normal BMI groups, specifically LGA, cesarean section, and excessive PWR. IOM ranges were more protective for preterm birth and SGA in the underweight and normal BMI groups; and for LGA, cesarean section, and excessive PWR in the overweight and obese groups (Figure 3). To date, no previous study in Taiwan has performed a direct comparison of IOM and Taiwan GWG guidelines; however, risk assessment studies yielded results that are consistent with our findings. A large retrospective cohort study between 2009 and 2015 in a hospital that applied IOM guidelines and the western BMI cutoffs reported that GWG below the IOM guidelines increased the risk of SGA for women in the underweight (BMI<18.5) or normal weight (18.5≤BMI<25) groups, but not for women in the overweight (25≤BMI<30) and obese (BMI≥30) groups [10]. Another study that applied the Taiwan classification of GWG and BMI in case-control studies reported that normal (18.5≤BMI<25) and underweight (BMI<18.5) women who adhere to the IOM guidelines had a reduced risk of infant low birth weight [11]; however, following IOM guidelines for normal (18.5≤BMI<25) and overweight (25≤BMI<30) women could lead to an increased risk of macrosomia [12].

Our study assessed five adverse birth outcomes, which were selected by the IOM committee for their relevance in the American population, and for the well-established associations with GWG [2]. Without undermining the importance of those adverse birth outcomes for maternal and child health, the focus of public health may shift in Asian populations. While the incidence of low birth weight, preterm birth, and SGA is increasing, macrosomia (about 1%) and LGA are less prevalent in Taiwan [27]. Additional birth outcomes were associated with GWG in the Taiwanese population. Pre-pregnancy BMI of 18.5-24 followed by GWG of 10-14 kg could lead to better obstetric management, including reduced risks of low birth weight, preterm labor, cesarean delivery, preeclampsia, and gestational diabetes mellitus [28]. In a cohort of 1147 women from Taipei, maternal (gestational diabetes mellitus, dysfunctional labor, and cesarean delivery) and neonatal complications (macrosomia and meconium aspiration) were significantly associated with excessive GWG, but not with inadequate GWG, based on the IOM classification [9]. In addition, GWG below the values stipulated in the IOM guidelines was an independent risk factor for placental abruption, while preeclampsia was related to pre-pregnancy obesity, but not to excessive GWG [10]. A way to account for the trade-off between the outcomes could involve weighting technique according to the importance of the outcomes as agreed by specialists, e.g. obstetricians,

neonatologists, NICU nurses, etc. For example, SGA was selected as the least adverse outcome, while preterm birth, complicated delivery and preeclampsia were assigned 1.2-2.3 times higher weights by Japanese specialists [16].

Previous studies in Western and Asian populations have shown that pre-pregnancy weight status and GWG could be independent predictors of birth outcomes for mothers and infants [16,18,25,29,30]. In the absence of clear guidelines in Taiwan, pre-pregnancy BMI could be a more relevant target for public health interventions. Our results indicated that the normal BMI group had substantially lower probabilities of all the five outcomes than the overweight and obese groups. Therefore, entering pregnancy at normal BMI, with local cutoffs of 18.5–24 kg/m^2, should be advised.

Our study analyzed a large national sample, ensuring high generalizability of our results for the Taiwanese population and adequate statistical power of our analyses. However, our study presents the following limitations. First, our study population was likely to be healthier than the general population, due to the possibility of the non-participation of mothers with adverse birth outcomes. Second, using BMI for classification of weight status could lead to misclassification bias. BMI was reported to be a limited indicator of obesity and body composition, as people with lower BMI could still have levels of adiposity equivalent to those found in obese individuals when measured by bioelectrical impedance [31]. Although we applied local, empirically established cutoffs for BMI classification to reduce the risk of misclassification, the use of waist circumference, or bioelectrical impedance, for more accurate results is recommended in the future. Self-reported height and weight also could bias BMI estimates, although pre-pregnancy BMI based on self-reported values was shown as a reliable and valid estimate for population-based research and surveillance purposes [32]. Residual confounding was likely due to the absence of information regarding every potential confounder, including smoking and environmental exposures [33]. Taiwan Birth Cohort Study detected only 3% of smokers in a sample of Taiwanese pregnant women in 2005 [34]. Assuming that our sample represents a healthier population, the prevalence of smokers would likely to be even lower, and therefore, the effect of smoking would be undetectable.

Conclusions

We observed poor discriminative performance of the IOM and the Taiwan guidelines for GWG regarding the five adverse birth outcomes for mother and infant. Also, a comparison between the predicted probabilities for each outcome did not support a preference for either set of recommendations. Physicians and health care workers need to individualize prenatal advice regarding GWG while following up-to-date research in local and world populations. Future research in large representative samples is required to assess optimal GWG ranges for Asian women and adverse perinatal outcomes, which are relevant to the local population.

Abbreivations

AUC – area under the receiver-operator curve

BMI – body mass index

GWG – gestational weight gain

HPA – Taiwan health promotion administration

IOM – American institute of medicine

LGA – large for gestational weight

PWR – postpartum weight retention

SGA – small for gestational weight

Declarations

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Tables

Table 1. Characteristics of Taiwanese primiparous women with singleton pregnancies based on pre-pregnancy body mass index (N= 31653).

ANOVA – analysis of variance, BMI – body mass index, SD – standard deviation

Table 2. Comparison of areas under receiver-operator curves for the American Institute of Medicine guidelines and the Taiwan recommendation for gestational weight gain (N= 31 653).

AUC – area under the curve, BMI – pre-pregnancy body mass index, IOM – American Institute of Medicine, LGA – large for gestational age, PWR – postpartum weight retention SGA – small for gestational age
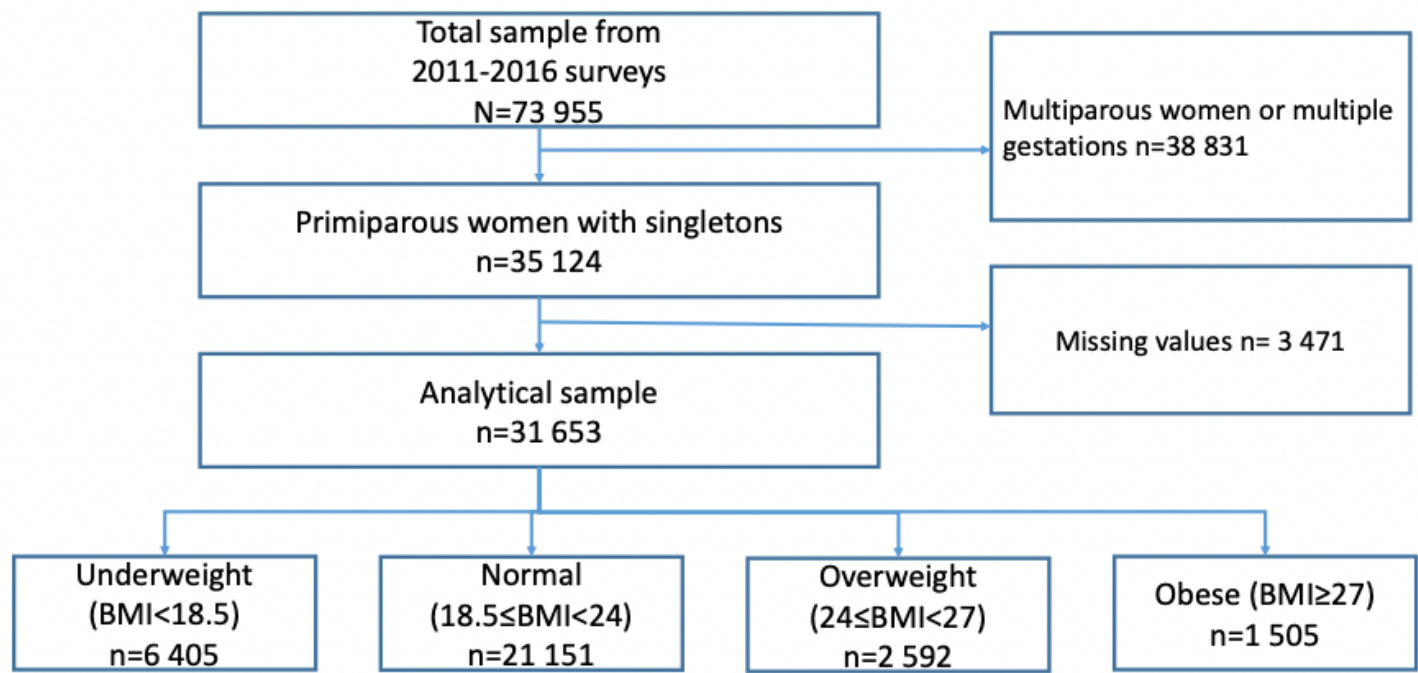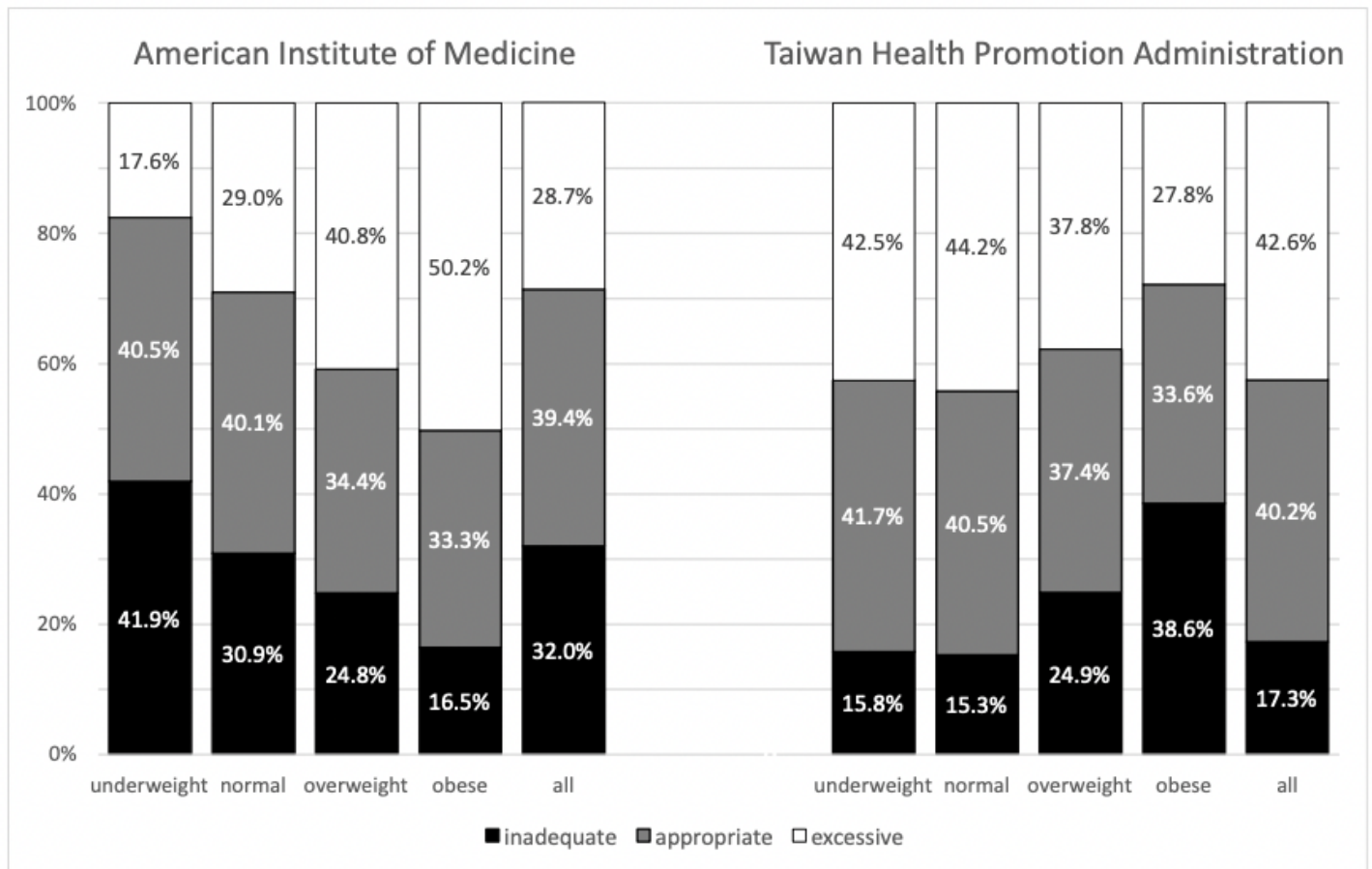
Figures

Figure 1

Flowchart of sample selection

	All	Underweight BMI<18.5	Normal 18.5≤BMI<24	Overweight 24≤BMI<27	Obese BMI≥27	p-values
	N=31,653	n=6,405	n=21,151	n=2,592	n=1,505	ANOVA
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	
Gestational weight gain, kg	13.9±5.2	14.1±5.0	14.2±5.0)	13.1±5.8	11.2±6.4	<0.001
	%(n)	%(n)	%(n)	%(n)	%(n)	χ^2 test
Preterm delivery	6.2(1,965)	6.0(382)	5.9(1,254)	7.1(183)	9.7(146)	<0.001
Small for gestational age	11.5(3,653)	15.2(972)	10.8(2,285)	10.2(264)	8.8(132)	<0.001
Large for gestational age	7.7(2,423)	4.3(277)	7.4(1,568)	12.4(321)	17.1(257)	<0.001
Cesarean section	33.0(10,454)	28.3(1,811)	32.3(6,839)	40.5(1,049)	50.2(755)	<0.001
Excessive postpartum weight retention	29.8(9,446)	24.4(1,562)	30.5(6,452)	37.5(972)	30.6(460)	<0.001
Age						<0.001
20–24	8.5(2,702)	13.9(890)	7.2(1,529)	6.8(175)	7.2(108)	
25–29	30.0(9,480)	35.8(2,290)	28.7(6,064)	27.7(717)	27.2(409)	
30–34	43.3(13,697)	39.0(2,499)	44.9(9,501)	42.1(1,091)	40.3(606)	
35 or older	18.2(5,774)	11.3(726)	19.2(4,057)	23.5(609)	25.4(382)	
Education						<0.001
Junior high or lower	2.8(899)	3.6(233)	2.6(542)	3.1(79)	3.0(45)	
High school	21.6(6,837)	26.9(1,722)	19.2(4,059)	23.6(611)	29.6(445)	
Vocational school	15.1(4,780)	13.9(890)	15.0(3,167)	16.9(437)	19.0(286)	
University or higher	60.5(19,137)	55.6(3,560)	63.3(13,383)	56.5(1,465)	48.4(729)	
Country of origin						<0.001
Taiwan	94.8(30,002)	91.8(5,877)	95.2(20,133)	97.4(2,524)	97.5(1,468)	
Other	5.2(1,651)	8.2(528)	4.8(1,018)	2.6(68)	2.5(37)	
Employment						<0.001
Not employed	38.4(12,166)	45.5(2,914)	36.1(7,645)	37.9(982)	41.5(625)	

Employed	61.6(19,487)	54.5(3,491)	63.9(13,506)	62.1(1,610)	58.5(880)	
Newborn sex						0.932
Female	48.0(15,183)	47.9(3,065)	48.1(10,170)	47.6(1,233)	47.5(715)	
Male	52.0(16,470)	52.2(3,340)	51.9(10,981)	52.4(1,359)	52.5(790)	
Was newborn healthy at birth?						<0.001
Yes	82.3(26,057)	85.4(5,471)	82.2(17,384)	79.2(2,054)	76.3(1,148)	
No	17.7(5,596)	14.6(934)	17.8(3,767)	20.8(538)	23.7(357)	

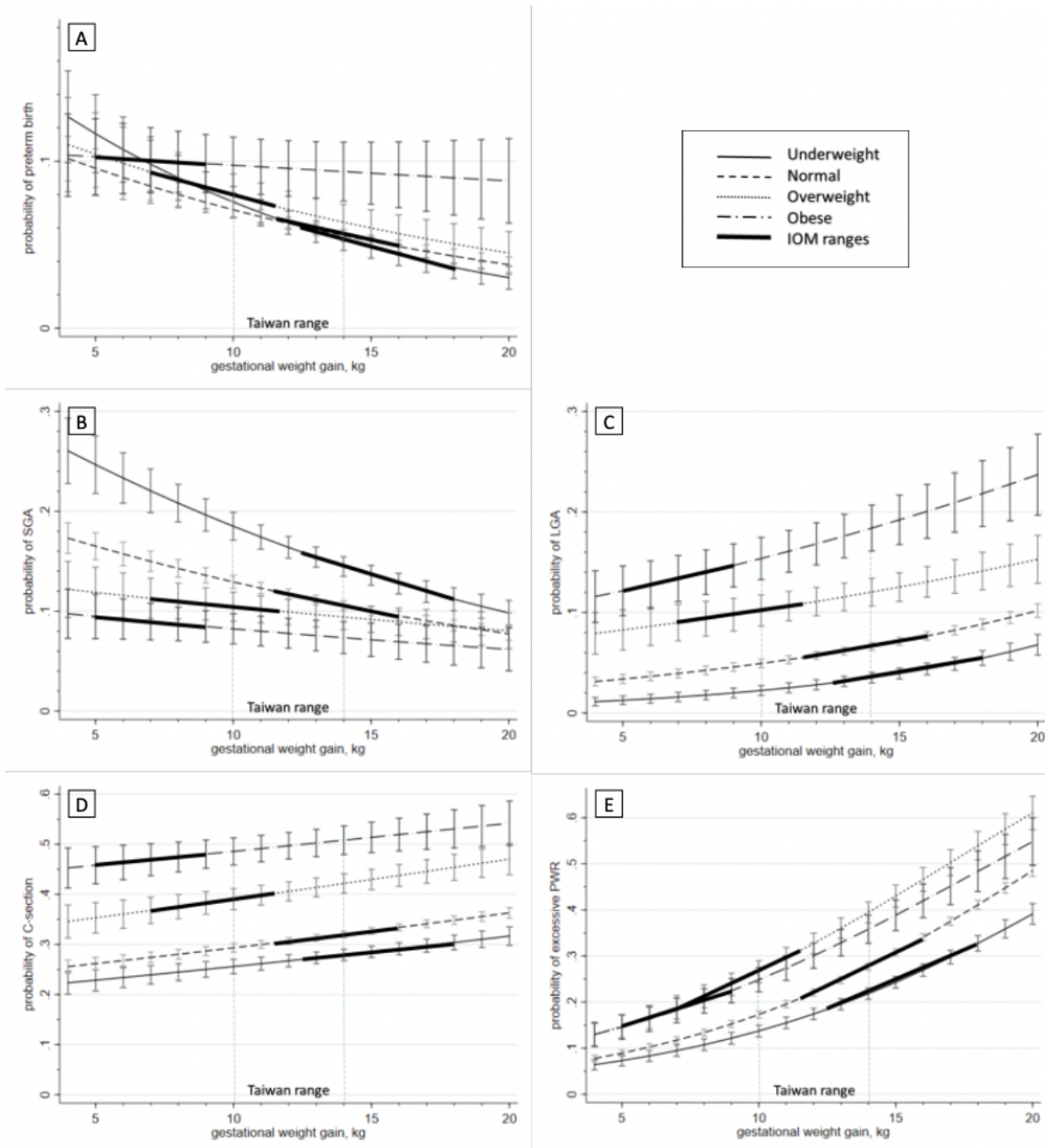|	Preterm birth		SGA		LGA		Cesarean section		Excessive PWR	
	AUC	p-value	AUC	p-value	AUC	p-value	AUC	p-value	AUC	p-value
All										
Taiwan	0.64	<0.001	0.58	0.01	0.62	<0.001	0.72	<0.001	0.68	<0.001
IOM	0.63		0.59		0.65		0.73		0.69	
Underweight, BMI<18.5										
Taiwan	**0.61**	**<.001**	0.59	0.597	0.64	0.502	0.53	0.081	0.66	0.693
IOM	**0.57**		0.58		0.65		0.54		0.66	
Normal, 18.5<BMI≤24										
Taiwan	0.58	0.860	0.57	0.592	**0.59**	**0.008**	0.53	0.107	**0.66**	**<0.001**
IOM	0.58		0.57		**0.60**		0.54		**0.67**	
Overweight, 24<BMI≤27										
Taiwan	0.56	0.924	0.55	0.901	0.56	0.855	0.55	1.000	**0.69**	**0.026**
IOM	0.56		0.54		0.55		0.55		**0.67**	
Obese, BMI≥27										
Taiwan	0.53	0.552	0.56	0.361	0.61	0.415	0.53	0.470	**0.70**	**0.001**
IOM	0.51		0.57		0.60		0.54		**0.67**	

ᵃ 12.5-18 kg for BMI<18.5, 11.5-16 kg for 18.5≤BMI<25, 7-11.5 kg for 25≤BMI<30, 5-9 kg for

BMI≥30

ᵇ 10-14 kg

ᶜ Categorization of body mass index with Taiwan cutoffs of 18.5, 24, and 27 kg/m²

Figure 2

Distribution of gestational weight gain categories according to the American Institute of Medicinea and the Taiwan Health Promotion Administrationb recommendations among pre-pregnancy body mass index categoriesc (N =31 653).

* Categorization of body mass index with Taiwan cutoffs of 18.5, 24, and 27 kg/m²

IOM – American Institute of Medicine, LGA – large for gestational age, SGA – small for

gestational age, PWR – postpartum weight retention

Figure 3

Predicted probabilities and 95% confidence intervals of adverse birth outcomes based on pre-pregnancy body mass index* (N=31 653).

Supplementary Files

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- Supplementary.docx