Memoranda/Mémorandums

Maternal anthropometry for prediction of pregnancy outcomes: Memorandum from a USAID/WHO/PAHO/MotherCare meeting*

The meeting discussed two main areas concerning maternal anthropometry in developing countries: (1) how various anthropometric indicators can be best utilized for assessing and monitoring the nutritional status of women at different times in their reproductive lives, and (2) the predictive value of various anthropometric indicators for identifying benefit or risk for maternal and perinatal/neonatal health and nutritional outcomes of pregnancy. The indicators discussed were prepregnancy weight, height, weight gain in pregnancy, arm circumference, weight-for-height and body mass index (weight (kg)/height (m)^2). Some 50 experts reached consensus on the tools for assessing maternal nutritional status for widespread field application in developing countries, and on priority research needs. This Memorandum summarizes the general recommendations which have important and immediate field applications, as well as priority research issues related to specific indicators.

Introduction

During pregnancy, anthropometric measures such as maternal weight gain, weight-for-height, or arm circumference have been shown to be good predictors of infant outcomes such as birth weight and survival. Although less research has been focused on the relationship between maternal nutritional status and maternal outcomes of pregnancy, studies have shown that anthropometric measures such as maternal height or arm circumference are useful in predicting outcomes such as cephalopelvic disproportion or poor postpartum maternal energy. Although these maternal and infant outcomes of pregnancy are related to maternal nutritional status as measured by anthropometry, many questions remain. To seek answers and to identify the most appropriate anthropometric indicators for use in field programmes, USAID, WHO, PAHO and MotherCare sponsored an international meeting on Maternal Anthropometry for Prediction of Pregnancy Outcomes in Washington, DC, USA, on 23–25 April 1990. Participants were from universities, research institutions, field programmes, organizations interested in maternal nutrition including UNICEF, the World Bank, and the US National Center for Health Statistics (NCHS), and from the sponsoring agencies.

General recommendations

Maternal anthropometric indicators have been useful for screening women at nutritional risk, monitoring maternal nutritional status, and predicting unfavourable infant outcomes related to pregnancy (low birth weight (LBW), perinatal, neonatal and infant mortality, and poor infant growth). Their application for screening, monitoring or evaluating risk for adverse maternal outcomes has been limited, but there is evidence that they are useful in this

* This Memorandum is based on a report prepared by Katherine Krasovec and Mary Ann Anderson. The complete conference proceedings will be published as a PAHO scientific publication. For further information, contact MotherCare, John Snow, Inc., 1616 North Fort Myer Drive, 11th Floor, Arlington, VA 22209, USA. The participants at the meeting were L. Adair, K.N. Agarwal, M.A. Anderson, E. Atalah, G. Berggren, P. Caplan, E. Casanueva, R. Clay, R. Fescina, S. Garn, M. Griffiths, T. Gonzales-Cossio, M. Gueri, G.R. Gupta, J. Haas, G.G. Harrison, S. Huffman, M.A. Husaini, A. Kelly, M. Koblinsky, K. Krasovec, R. Kuczmarski, J. Kusin, A. Lechtig, C.M. Longmire, R. Martorell, J. McGuire, K. Merchant, R. Naeye, C. Neumann, J. Oki, M. Pena, N. Pielemeier, A. Pradilla, H. Rey, P. Rosso, K. Shah, P.M. Shah, D. Sinha, A. Siqueira, N. Sloan, E.N. Suarez-Ojeda, J. Tognetti, M. Vargas, O.A.C. Viegas, J. Yunes, and A. Zerfas.

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respect as well, particularly in regard to specific indicators and specific outcomes (e.g., maternal height for risk of cephalopelvic disproportion (CPD), and maternal arm circumference during pregnancy for risk of depleted maternal stores as evidenced by maternal weight for body mass index (BMI) at 1–6 months postpartum). Field applications and research priorities are presented together since many conclusions combine the two.

(1) Research and programmes should focus on three major outcomes: low birth weight (LBW) relating to infant mortality, morbidity and growth; pregnancy complications (primarily for the mother); and maternal stores. Although these outcomes are connected, a focus on any one does not provide adequate information on what is happening to the other two. Measures of maternal outcomes of pregnancy (e.g., pregnancy complications such as prolonged/obstructed labour) and postpartum maternal nutritional status (as well as food intake and physical activity) should be added to intervention trials.

(2) Programmers and researchers should recognize and distinguish between four groups of women of childbearing age, each group having different needs: (*a*) pregnancy; (*b*) lactating; (*c*) pregnant and lactating concurrently; and (*d*) non-pregnant, non-lactating. Cut-off points and changes in some indicators may have different interpretations for these four groups.

(3) The high pregnancy weight gains necessary to ensure favourable pregnancy outcomes for women of low prepregnancy weight may be unrealistic for many developing country women. Therefore, equal emphasis should be placed on improving prepregnancy or non-pregnancy weights of developing country women, so that women do not enter pregnancy in a nutritionally disadvantaged state.

(4) Adolescents have additional nutritional requirements during pregnancy and need special attention from programmes. In research, adolescent pregnancies should be examined separately whenever possible.

(5) Anthropometric indicators identify women with nutritional problems, but do not reveal the determinants of the problem. The cause may be related to inadequate energy intake, specific nutrient deficiencies, infections, endemic diseases such as malaria, high energy expenditure, etc. Once a maternal nutritional problem has been indicated anthropometrically, one needs to identify the determinants of the problem in order to design appropriate actions to improve maternal nutritional status; one should not measure without a purpose. Possible interventions include: community, family or individual nutrition education and diagnosis of problems; altering intrafamilial food distribution and increasing household food security; provision of additional food to pregnant and lactating women; reduced work loads; family planning; community development activities; and treatment of infection. Furthermore, surveillance or surveys to quantify and raise one's awareness of the extent of maternal malnutrition are also needed.

(6) Both epidemiological and programmatic considerations should be taken into account when choosing cut-off points for specific indicators. In epidemiology, cut-off points indicate the point in the distribution of the indicator under which increased evidence of adverse consequences for the mother or infant are observed in a given setting. In determining cut-off points, relative risk is less important than attributable risk. Where the relationship between an indicator and an outcome is non-linear with a visible threshold (e.g., the U-shaped relationship between gestational weight gain for a given prepregnancy weight and perinatal mortality in the U.S. (*32*), the choice of a cut-off point is clear. However, if the relationship between an indicator and an outcome in a particular setting is linear (e.g., the relationship between height and contracted pelvis or cephalopelvic disproportion in Nigeria (*9*)), the choice of a cut-off point may be more arbitrary. If the relationship between an indicator and outcome is linear, and a threshold relationship exists between the outcome of interest (e.g., birth weight) and a more distant and serious outcome (e.g., perinatal mortality), one would ideally set a cut-off point at that birth weight above which survival is more likely (usually 2500 g).

(7) In determining the most appropriate cut-off points for a programme, one should consider the distribution of the indicator, the prevalence of the risk factor, the prevalence of the outcome, and the relationship between the indicator and the outcome (the sensitivity and specificity distributions) in the population of interest, as well as programmatic considerations such as the resources available to deal with the problem and the type of intervention to be employed. Although ideally cut-off points will be determined by the epidemiological situation, in practice the scarce resources and a large nutritional problem may compel a programme to choose a programmatic cut-off point that is lower than an epidemiologically determined cut-off point. This should be considered as only a short-term approach, and creative solutions should be sought to deal with resource constraints.

(8) Anthropometry may interact with other factors (such as morbidity) in its relationship with pregnancy outcomes. Thus, a particular value of an indicator may have a different meaning in different settings. Although some cut-off points are universal (i.e., a minimum weight gain of 1 kg/month in the

second and third trimester of pregnancy), more often cut-off points are regional or country-specific, or specific to certain categories of women (e.g., a cut-off point for prepregnancy weight for women between 140 and 150 cm tall). Specific cut-off points are discussed in the sections on each indicator.

(9) Cut-off points for an anthropometric indicator may be different for women's outcomes as opposed to infants' outcomes. More research needs to be done to determine the most appropriate cut-off points for different outcomes.

(10) Commonly used anthropometric references for adult women represent averages of the healthy populations studied and should not necessarily be interpreted as standard. Research is needed to develop standards by determining the distribution of different anthropometric indicators in women that are predictive of favourable and unfavourable pregnancy outcomes and women's outcomes regardless of reproductive status.

(11) Approximately 70 million pregnancies occur each year in settings where the routine health services lack weighing scales or where the available scales are not in working order. Where it is logistically difficult to measure and monitor individual women, the use of population-based, rather than individual-based, assessment and monitoring was suggested in order to target interventions to regions with the most severe nutritional problems.

(12) Lessons learned from growth monitoring of children are useful for monitoring changes in nutritional status of women: (*a*) measuring (on a routine basis) is a means to an end and not an end in itself, and one must intervene when a nutritional problem is identified; (*b*) weight gain velocity during pregnancy may be more useful than the attainment of a specific weight gain by a specific gestational age, or the assessment at one point in time compared to a reference population; (*c*) much can be done in the home by the women or communities themselves (i.e., using home-based maternal records, arm circumference measurement, etc.); and (*d*) women understand the concepts of weight gain in child growth monitoring and thus should be able to apply the same understanding to interpreting their own weight change in pregnancy.

(13) Although not discussed in detail, combinations of anthropometric indicators or anthropometric indicators in tandem with other types of indicators have proved useful in several studies and programmes for increasing the predictive value of these measures. This has important programmatic implications, and specific combinations (prepregnancy weight and a single weight during pregnancy, prepregnancy weight (or weight-for-height) and gestational weight gain, arm circumference and gestational weight gain, arm circumference and height) were recommended for further research. Two additional measures of research interest were anaemia and uterine height. Anaemia in combination with anthropometric measures of maternal undernutrition may improve one of the poor pregnancy outcomes. Uterine height may be a good predictor of LBW and infant outcomes of pregnancy.

(14) More research was recommended to answer whether one indicator should be used as a proxy for another, i.e., to what degree are measures interchangeable. Specific questions were: (*a*) How long a period prior to pregnancy (1 year maximum) is a non-pregnancy weight a valid approximation of prepregnancy weight taken in the month prior to conception? (*b*) What is the relationship between the weight or arm circumference at first visit during pregnancy and the prepregnancy weight? (*c*) What is the relationship between the arm circumference and maternal or infant outcomes for women with different body compositions? (*d*) What is the overlap between indicators—do women who are low weight-for-height also show low height or low arm circumference?

(15) Biological research is needed on the relationships between specific anthropometric indicators and specific pregnancy outcomes to determine the causal pathways. Though understanding of the causal mechanisms is not critical for screening purposes, it is extremely important for designing appropriate interventions since actions to change the anthropometric indicator will only result in changing the outcome if there is a causal relationship between the indicator and the outcomes.

Indicator-specific recommendations

Prepregnancy weight

Prepregnancy weight has been shown in many studies in developed and developing countries to be related to birth weight and infant mortality (*18*, *19*, *32*). Although prepregnancy weight and weight gain in pregnancy are related, prepregnancy weight has an independent effect on birth weight from that of weight gain and other factors (*4*, *47*). The combination of low prepregnancy weight and low pregnancy weight gain, which occurs in many developing country women, is very detrimental to infant outcomes of pregnancy. The relationship between pregnancy weight and maternal outcomes of pregnancy has not been adequately addressed.

- *Field applications*

(1) Women with very low prepregnancy weights need large gestational weight gains (up to 18 kg) in

order to significantly lower their risk of unfavourable pregnancy outcomes (*16*). These large weight gains may be unrealistic for many developing country women. Therefore, equal emphasis should be placed on improving prepregnancy or non-pregnancy weights, so that women do not enter pregnancy in a nutritionally disadvantaged state.

(2) Within populations where the average height of reproductive-age females of low socioeconomic status (SES) is around 150 cm (including India, Bangladesh, Indonesia, Colombia), a prepregnancy weight of <40 kg has been found to be a good predictor of LBW and neonatal mortality.

(3) Although prepregnancy weight is very useful, it may be difficult to obtain in developing countries where it is not common to measure the mutritional status of non-pregnant women (*1*).[a] In these circumstances, the weight measured in the first trimester of pregnancy may be used as an indication of prepregnancy status, with some adjustment.

(4) Prepregnancy weight should be interpreted in relation to height to be useful for *cross-population* comparisons.

(5) In populations with low prepregnancy weight and low pregnancy weight gains, the prepregnancy weight alone may be a good predictor of negative pregnancy outcome. Under these circumstances, weight gain may not have a high predictive value because the weight gains are low, with little variability. These are often the same settings where monitoring of gestational weight gain is very difficult because of poor health service infrastructure. Under these conditions, it is acceptable and more feasible to use the prepregnancy weight or a single weight taken early in pregnancy as a predictor of negative pregnancy outcome (*7, 38*).[a]

(6) Opportunities for weighing women when they accompany a child for growth monitoring, immunizations, health check-ups, supplementary feeding programmes, etc., should be seized. Other ways of reaching nulliparous women need to be devised. This weight (and the date it is taken, as well as the woman's reproductive status) can be recorded on home-based or clinic-based maternal records. This weight may be useful in identifying women who are at nutritional risk and for whom interventions can be targeted *prior to pregnancy*. The usefulness of this weight as a proxy for the prepregnancy weight depends on its proximity to the date of conception and requires further validation.

(7) Prepregnancy obesity is also a risk factor for unfavourable pregnancy outcomes such as perinatal mortality, high birth weight (when combined with high pregnancy weight gain) and infant mortality and needs to be taken into account especially in Latin America where the prevalence of obesity (defined as greater than 120% of reference weight for height) may be as high as 30%.

- *Research priorities*

(1) Validating use of the weight measured in the first trimester of pregnancy as a proxy for the prepregnancy weight.

(2) Determining how long before pregnancy a woman's non-pregnant weight can be used as a proxy for her prepregnancy weight (or weight at conception).

(3) Testing interventions to increase women's weight before pregnancy or during the interpregnancy interval in order to improve subsequent pregnancy outcomes.

Weight gain in pregnancy

Appropriate weight gain in pregnancy is critical to maternal and infant outcomes of pregnancy. Optimal weight gains are different for women who begin pregnancy at different nutritional levels. Women with low prepregnancy weights need to gain more weight during pregnancy than women who are of average weight or overweight. The combination of low prepregnancy weight and low weight gain during pregnancy puts women at the greatest risk of delivering a low-birth-weight infant (*37, 43, 47, 49, 54*). The effect of weight gain on intrauterine growth retardation has been shown in many studies to be greater for undernourished women and for women during times of acute nutritional stress (e.g., famine or season of food scarcity) (*19, 32, 36, 42*).[b] A causal effect of weight gain on gestational duration cannot be ruled out with the available evidence (*19*). Low weight gain in pregnancy is also related to fetal and neonatal mortality (*32, 49*).

Recent U.S. guidelines for weight gain in pregnancy call for differential weight gains based on prepregnancy status. Recommendations for underweight women (BMI < 19.8) are for a total gestational weight gain of 12.5–18 kg. Recommended weight gains for women who prior to pregnancy are normal weight (BMI of 19.8–26.0), overweight (BMI 26.0–29.0) and obese (BMI > 29.0) are 11.5–16 kg, 7–11.5 kg and at least 6 kg, respectively (*16*). However, average weight gains for women in developing countries (5–9 kg) are much lower than

[a] **Anderson, M.A.** *The relationship between maternal nutrition and child growth in rural India*. Ph.D. dissertation, Tufts University, 1989.

[b] **Beteta, C.** [*Pregnancy and nutrition*.] Thesis, Universidad de San Carlos, Guatemala, 1963 (in Spanish).

these recommendations and also much lower than the average weight gains reported for women in developed countries (10.5–13.5 kg). These differences in weight gain parallel the differences in incidence of LBW between developing countries and developed countries (*55*, *56*).

• *Field applications*

(1) Wherever feasible, monitoring of weight gain during pregnancy should be undertaken. Although such monitoring is desirable, in countries where <30% of the population receives prenatal care it may not be feasible. Where weight gain monitoring is not feasible, *screening* with measurements that require only one contact with a woman, such as pre-pregnancy weight (or weight-for-height or arm circumference), is still useful. In countries where about half of the women receive prenatal care, two weight measurements (one month apart in the second or third trimester) may be more feasible. In countries where more than half of the women receive regular prenatal care, and equipment and trained staff are available, repeated weighing should be the aim.

(2) Prepregnancy weight and pregnancy weight gain are independent and completely additive (and subtractive) in their effect on birth weight, together accounting for a difference of up to 1 kg in birth weight. Traditional weight gain by gestational age charts used for recording weight serially can be made more predictive of pregnancy outcome if the weight-gain curves are adjusted for prepregnancy weight, weight-for-height (or possibly, arm circumference). Women with a low prepregnancy weight or weight-for-height should be advised to gain more weight than average-weight or overweight women. Obese women need to gain the least amount of weight during pregnancy.

(3) Assessment of the velocity (or increment) of weight gain in the second or third trimester of pregnancy is a simplified means to monitor the weight gain in pregnancy. A minimum weight gain of 1 kg per month throughout the second and third trimester is recommended. Two measurements can be taken, at least one month apart, at any time during the second or third trimester to make sure the women are gaining at least 1 kg per month. Lack of weight gain or weight loss is very detrimental to the fetus and mother and requires immediate action. A major advantage of this method is that the gestational age need not be known; it is only necessary to know that a woman has reached or passed the second trimester in pregnancy.

(4) Taking only two measurements of weight, one month apart, in the second or third trimester is far more feasible than taking repeated serial measurements, and it is still predictive of pregnancy outcome. Weight gain is less variable in the second and third trimesters than it is earlier in pregnancy. The first measurement could be taken around the time that the fetus starts to move (around 10 weeks' gestation), since the monthly weight-gain increments in reference populations are fairly constant from then onwards.

• *Research priorities*

(1) Developing a portable, durable, accurate, and inexpensive adult weighing scale, and making it available.

(2) Assessing the consequences of a low pregnancy weight gain for the mother.

(3) Adapting the methods, tools, educational approaches and lessons learned from child growth monitoring to the assessment of weight gain in pregnancy.

(4) Developing pregnancy weight-gain charts which take the prepregnancy weight into account and which are appropriate for developing country women. In designing weight gain charts, one needs to be clear about the outcomes they are intended to predict and prevent, e.g., infant outcomes (LBW, mortality); pregnancy complications; or poor maternal stores postpartum. Charts need to be designed and interpreted accordingly, with the aim of having one chart that can serve various purposes.

Height

Height has been used to screen for risk of poor pregnancy outcomes such as low birth weight, perinatal, neonatal and infant mortality, and lactation duration (*15*, *19*, *24*, *29*, *35*, *41*, *42*, *47*, *52*, *53*). An independent contribution of height to infant outcomes of pregnancy (birth weight and mortality) has been found in several studies (*8*, *23*, *25*, *42*), but others argue, based on U.S. data, that maternal height does not have an effect on infant outcomes (birth weight and recumbent length) independent of maternal weight, muscle, or fat reserves, and that the influence of height on birth weight is simply a reflection of total maternal body mass (*6*, *44*).

Maternal height is also commonly accepted as a useful clinical indicator for risk of obstetric complications, particularly cephalopelvic disproportion (CPD), prolonged labour, or delivery by operative means such as Caesarean section, symphysiotomy or embryotomy. (*3*, *5*, *9*, *26*, *30*, *51*). Although maternal height is useful as an indicator of *risk* for these unfavourable outcomes of pregnancy, it is not useful as an indicator of outcome since a woman's height cannot be expected to change in response to intervention. There is, however, some evidence that adolescent girls do gain height in response to nutritional interventions (*10*).

• *Field applications*

(1) Maternal height is useful as a proxy for pelvic proportion and in turn as a predictor of the risk of difficult or obstructed labour and CPD.

(2) Country or region-specific maternal height cut-off points need to be established for predicting risk of LBW and CPD which maximize sensitivity and specificity. The range of cut-off points for predicting CPD and LBW is likely to fall between 140 and 150 cm.

(3) The usefulness of height alone as a predictor of LBW is generally limited and varies across populations. Its predictive value increases in combination with other measures, such as prepregnancy weight.

(4) Height is a good indicator of socioeconomic status and is useful to identify women at nutritional risk. As such, it may be useful for targeting nutritional interventions (*22*).

(5) A single height measurement, taken any time after adolescence can be used as an indicator of reproductive risk throughout a woman's lifetime.

• *Research priorities*

(1) Further testing of the association between maternal height and pregnancy complications such as risk of prolonged or obstructed labour and CPD.

(2) Exploration of the predictive value of alternative maternal anthropometric measurements, such as pelvic diameter (between iliac crests) or shoulder breadth (between the two acromia), for obstructed labour.

(3) Measurement of the potential for continued linear growth among malnourished teenagers during pregnancy and non-pregnancy periods.

(4) Evaluation of whether nutritional supplements for short women, which result in a larger baby, affect the infant's head circumference, and increase the probability of prolonged or obstructed labour or CPD. Increase in infant head circumference at birth as a result of maternal supplementation could be used as a proximate indicator of pregnancy complications for the mother.

Arm circumference

Recent evidence indicates that maternal arm circumference can be used as an indicator of maternal nutritional status in non-pregnant women because of its high correlation with maternal weight or weight-for-height (*12*, *39*, *50*)[c] and during pregnancy to screen for risk of LBW and late fetal and infant mortality (*21*, *24*, *46*)[c,d,e]. Maternal arm circumference is relatively stable during pregnancy in developing countries (*13*, *14*, *24*)[c,e] and is independent of gestational age.

• *Field applications*

(1) Maternal arm circumference can be used to assess the nutritional status of non-pregnant women and, prior to or during pregnancy, to identify women at risk of LBW and fetal or infant mortality.

(2) The usefulness of arm circumference for screening women at risk of poor maternal stores postpartum is promising because it reflects maternal fat and lean tissue stores and because of the high correlation between arm circumference and weight in pregnant and non-pregnant women.

(3) A concerted effort should be made to get arm circumference tapes to community level workers, especially traditional birth attendants (TBAs), and to train them in their use. In settings with limited infrastructure, arm circumference may be the only anthropometric indicator currently feasible to use.

(4) In more sophisticated settings, arm circumference can be used to screen and refer women to facilities for a more thorough assessment of nutritional risk. In these situations, the measurement of arm circumference complements weight, height or other indicators; as a criterion to refer women at the community level, arm circumference may stimulate the use of health services by those who need them most.

(5) Anthropometric data are often needed to quantify the extent of undernutrition in an area through surveillance or surveys. Measurement of arm circumference can be very useful for *rapid assessment* of the nutritional status of women and should, therefore, be incorporated into ongoing local and international surveys or surveillance systems. Similarly, cross-sectional surveys of arm circumference, repeated over time, may be useful for monitoring the nutritional status of populations. These assessments may be particularly useful in extreme situations such as among displaced populations or during extended periods of drought or famine.

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[c] See footnote *a* on page 526.

[d] **Atalah, E.** *Sensitivity and specificity of arm and calf circumferences in identifying undernourished pregnant women.* Department of Nutrition, Faculty of Medicine, Santiago, Chile, 1983 (unpublished).

[e] **Krasovec, K.** *An investigation into the use of maternal arm circumference for nutritional monitoring of pregnant women.* Sc.D. dissertation, Johns Hopkins University School of Hygiene and Public Health, 1989.

(6) On an individual level, routine monitoring of arm circumference during pregnancy is not recommended because the reported changes are often too small to detect in service settings.

(7) In situations where weight gain in pregnancy is routinely monitored but prepregnancy weights are not available, arm circumference taken at any time during pregnancy may serve as a useful proxy for prepregnancy weight. Hence, arm circumference may be used to guide the amount of weight gain that is advisable for individual needs.

(8) Arm circumference is attractive because the simple technology required and the information it delivers can be transferred to the women in their own homes and communities. For the purpose of assessing each other, women can be instructed on the use of a colour-coded tape or a tape marked by a cut-off point to indicate that action is necessary (*21*, *46*). Therefore, arm circumference assessment can be a tool for aiding and motivating the women.

(9) Measurement of arm circumference should not be restricted to pregnancy, but taken whenever a woman of childbearing age comes into contact with the service delivery system. This measurement can be used as an indication of a woman's prepregnancy or non-pregnant nutritional status.

(10) Arm circumference cut-off points for assessing biological risk of LBW and fetal and infant mortality are fairly consistent across developing country populations in Asia, Africa and Latin America in the range of 21–23.5 cm. The underlying epidemiological situation and programmatic concerns also need to be considered in determining appropriate cut-off points for programmes.

• *Research priorities*

(1) Functional significance of arm circumference for women with different body compositions (fat vs. lean mass in the upper arm) and the relationship between arm circumference and other fat deposition sites.

(2) Relationship between arm circumference and women's health and nutritional status. This includes, but is not restricted to, maternal or pregnancy-related outcomes.

(3) Investigation of changes in arm circumference over the reproductive period to compare dynamic to static measures of arm circumference in terms of their relative abilities to predict specific outcomes and to compare arm circumference changes to weight changes.

(4) Testing different instruments and if possible designing a universal one which is simple to use (such as colour-coded tapes).

(5) Determination of the advantages of different combinations of arm circumference with weight, weight-for-height, uterine height, head circumference, etc. in terms of improving the effectiveness and efficiency of interventions. A single tape that can be used to measure arm circumference and uterine height was also identified as potentially attractive.

(6) Establishment of the relationship between arm circumference early in pregnancy and prepregnancy weight (or weight-for-height).

(7) Development of weight gain charts which incorporate arm circumference as an alternative to prepregnancy or first-visit weight or weight-for-height, in order to tailor the weight gain recommendations for optimal outcomes to the individual woman's nutritional status, when the prepregnancy weight is unknown.

Weight-for-height and body mass index (BMI)

Body mass indices are used to assess thinness or obesity. The most commonly used indices are weight-for-height (weight as a percentage of reference weight at a given height) or body mass index (BMI) (weight (kg)/height (m)^2, sometimes referred to as the Quetelet index). Body mass indices are commonly used for monitoring of weight gain in pregnancy based on prepregnancy status, since thinner women need to gain more weight during pregnancy than average-size or heavier women in order to significantly lower their risk of unfavourable outcomes such as LBW, small-for-date infants and perinatal mortality (*2*, *11*, *32*, *36*, *40*, *43*, *45*). Weight-for-height is also used to monitor women throughout their pregnancy, not just to assess the initial status. A study in Chile found that women with a weight-for-height less than 90% of reference at any point in pregnancy had a relative risk of 2.6 for delivering small-for-date infants compared to women of normal weight-for-height.[f] Several researchers have shown that low maternal BMI is also associated with negative postpartum outcomes such as lower breastmilk output and underweight children (*20*).[g,h]

• *Field applications*

Weight-for-height (non-pregnant women)

(1) It is useful to screen women of reproductive age for low weight-for-height and to intervene to increase the weight prior to pregnancy, since this

[f] See footnote *d*, page 528.

[g] See footnote *a*, page 526.

[h] **Fakambi, L.** *The factors affecting indicators of undernourishment in mothers: the case of women in the Food and Nutrition Program of the Ouando Horticulture and Nutrition Center in the People's Republic of Benin.* Final Report. International Center for Research on Women, 1990.

weight is so critical to the pregnancy outcome and maternal well-being.

(2) The interpretation of weight-for-height data to determine normalcy in the individual woman is problematic, because of the absence of reference tables based on functional outcomes. Commonly used references contain normative information only.

(3) In order to make the interpretation of weight-for-height simpler for health workers, there is a need for tools like the ready reckoner, colour-coded Nabarro & McNab Thinness Chart (*31*) used in children. The ability of workers at different levels of the health system to use nomograms for weight-for-height has not been widely tested.

(4) The 1959 U.S. Metropolitan Life Insurance Tables have been used as a weight-for-height reference for women with heights of 145 cm and above. More recent surveys, including the 1983 Metropolitan Life Insurance Tables and the U.S. National Health and Nutrition Examination Surveys I and II (*33*, *34*) are plagued by the problem of a progressive secular trend towards increasing weights in the U.S. population. This makes use of the more recent data less appropriate than the 1959 Metropolitan Life references. Moreover, desirable reference standards in both Metropolitan tables (*27*, *28*) were determined by the longevity of high socioeconomic status women, and bear no necessary relationship to optimal prepregnancy weight. Despite these limitations, until appropriate references for prepregnancy weight are established based on suitably representative populations and tested against obstetric outcomes, the 1959 reference standards should be used for women taller than 145 cm.

(5) Women should have a weight-for-height taken 4–6 weeks postpartum to determine maternal stores resulting from weight gain in pregnancy. This indicator should be used to assess pregnancy outcome for the woman.

Weight-for-height (pregnant women)

(1) Weight gain recommendations in pregnancy are more valid for predicting normal birth weight when adjusted for prepregnancy weight and height. The most widely known are Rosso's chart (*43*) or several adjusted weight-gain charts used by various states in the U.S. in the Special Supplemental Food Program for Women, Infants and Children (WIC). These charts advise higher weight gains for women with low prepregnancy weight and lower gains for overweight women so that all women achieve 120% of weight-for-height (by the 1959 Metropolitan Life Insurance Tables) at term (*16*).

(2) Pregnancy weight-gain charts based on weight-for-height and prepregnancy weight-for-height may be too difficult to use at the community level, but may be appropriate for use in health centres with equipment and well-trained staff with sufficient time. Another limitation of such charts is that accurate gestational age must be known, but often is not.

Body mass index (BMI)

(1) BMI (weight (kg)/height (m)^2) is a ratio with weight disproportionately weighted and therefore highly correlated with weight itself. Similarly, in adult women the BMI is highly correlated with weight-for-height and is essentially just a different way of presenting the same information as weight-for-height.

(2) BMI may not be a practical tool for field workers in service delivery programmes in developing countries because of its complicated, mathematical nature. It is better suited for use in research projects.

(3) The main advantage of BMI is that since it is a self-contained, calculated ratio, it requires no reference tables, in contrast to weight-for-height. Since no population-specific reference values are used to calculate it, the BMI becomes a more convenient indicator for comparisons between studies internationally. Cut-off points suggestive of chronic energy deficiency in adults (e.g., BMI < 18.5) have been established by the International Dietary Energy Consultative Group (*17*) but require validation against maternal and infant outcomes of pregnancy.

(4) Wherever weight and height data have been collected in research projects or surveys it would be helpful to convert and present them as the BMI in order to facilitate comparisons between studies. However, the same BMI in different countries may mean different things owing to variations in body composition.

- *Research priorities*

(1) Development of weight-for-height reference data, based on appropriately representative populations and tested against maternal and infant outcomes of pregnancy (sensitivity and specificity distributions).

(2) Development of weight-for-height reference data for women of short stature (<145 cm) for whom no desirable weight-for-height data exist. This could be done using developing country populations. One such approach, used in a low-income, short-stature population in India by Anderson,[i] needs to be validated in other populations.

(3) Validation of BMI cut-off points recommended by the International Dietary Energy Con-

[i] See footnote *a*, page 526.

sultative Group (*19*) for defining chronic energy deficiency (i.e., < 18.5, and subcategories of Chronic Energy Deficiency, Grades I, II, and III) for functional outcomes for the mother and infant, since BMI cut-off points have been determined historically according to the mortality risks associated with obesity. Identification of appropriate BMI cut-off points for both pregnant and lactating women is needed.

(4) Determination of the need for different interpretation of reference data for weight-for-height and BMI for non-pregnant women, those who are planning on becoming pregnant in the near future, adolescents, lactating women, and non-lactating postpartum women. Norms for maternal weight changes during lactation from 0 to 24 months postpartum also need to be established.

(5) Exploration of the functional consequences of BMI or weight-for-height at different heights. Is there a different significance from being thin (or obese) at 140 cm as opposed to 165 cm? Does the same BMI at different heights reflect similar body composition?

(6) Investigation into whether a pregnancy weight gain which results in an attained weight at term of less than 120% of the reference weight-for-height (such as 110%) can be recommended as a minimum weight gain sufficient to prevent LBW and unfavourable maternal pregnancy outcomes in developing countries. Although achievement of 120% of the reference weight-for-height by term may be ideal for producing *normal* birth weight infants, it may not be necessary to significantly lower the risk of *low* birth weight and related mortality. It may be more feasible to achieve 110% of weight-for-height by term in many developing country settings where prepregnancy weights are very low. In addition, a weight gain of 120% reference weight-for-height may not be the optimal gain for maternal health.

(7) Assessment of the feasibility of measuring weight-for-height or BMI and using nomograms as screening or monitoring tools in service delivery programmes in developing country settings and comparison with the feasibility and ability to predict pregnancy outcomes from weight alone.

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