1. Introduction

A workplan on maternal nutrition for WHO's Maternal and Child Health, Family Planning and Nutrition programmes was developed in 1988 in response to requests from the World Health Assembly. There was a clearly defined need to provide guidance to national health services on practical ways of assessing women's nutritional status, particularly in relation to reproduction. Numerous studies had previously investigated indicators based on maternal anthropometry for purposes of predicting infant and, less frequently, maternal outcomes of pregnancy. Indicators such as maternal height, pre-pregnancy weight, gestational weight gain, and mid-upper-arm circumference received considerable attention as proxy measures of current or past nutritional status, which in turn bear directly or indirectly on pregnancy outcome, particularly in relation to infant birth weight.

Krasovec & Anderson (*1*) summarized the deliberations of a recent international meeting on this topic and identified programme and research issues in the use of individual indicators as well as providing an up-to-date literature review. The international meeting identified two areas of maternal anthropometry as priorities for further investigation:

— the lack of definitive recommendations on preferred indicators for specific pregnancy outcomes in different primary health care settings;

— the consistency of performance of individual indicators in different populations and under varying operational conditions.

As part of the WHO workplan it was therefore decided: (*a*) to test the performance of selected indicators in predicting various pregnancy risks for both infant and mother, and (*b*) if indicators were found to have a useful predictive role, to develop suitable reference values for screening and monitoring. One immediate application for these reference values would to be expand the WHO prototype home-based maternal records (*2*) to include monitoring of nutritional status. A joint agreement to finance the workplan was signed between WHO and USAID that led to complementary funds being made available by USAID during 1988–92.

Scope of the project

Various studies conducted in different settings have identified a range of potentially useful indicators. Under study conditions, with reliable equipment and trained personnel, these have reportedly demonstrated good predictive value. Unfortunately, such study conditions are not widespread in routine service operations and thus actual performance may be significantly poorer than expected. There is therefore a need to provide sound technical advice on the utility and feasibility of selected anthropometric indicators for routine application in primary health care, especially in circumstances where resources are limited. This concern led to a jointly sponsored WHO/PAHO/USAID/MotherCare conference on maternal anthropometry (23–25 April 1990), which focused specifically on identifying appropriate anthropometric indicators for field application. The conference discussed in detail the strengths and weaknesses of single anthropometric indicators such as maternal height, weight, gestational weight gain, arm circumference, body mass index, and weight-for-height in relation to both maternal and fetal outcomes (*3*). This meeting was immediately followed by a further consultation under the auspices of WHO/PAHO (26–27 April 1990), in collaboration with USAID/MotherCare, to address the practical issues of developing a framework for the re-analysis of existing data sets in order to permit a comprehensive assessment of the available evidence. A decision was taken to proceed with a large-scale secondary analysis of data, followed by a meta-analysis of existing data sets on maternal anthropometry and pregnancy outcomes. The meeting also assisted in the identification of appropriate data sets and endorsed the proposal to contact investigators and request their support in re-analysing their data according to a standard protocol.[a] Arising from these analyses, practical guidance would be offered to health planners and field workers on the expected performance of selected indicators.

Rationale for analysis strategy

The decision to undertake a re-analysis of existing data, as distinct from undertaking a multicentre prospective study, was dictated by three considerations:

— the existence of a sufficient number of suitable data sets to permit the project objectives to be met;

— the lower cost of re-analysis of existing data compared with launching a new multicentre prospective study; and

[a] *Protocol for secondary data analysis of existing data bases on maternal anthropometry.* WHO Nutrition Unit and Programme of Maternal and Child Health and Family Planning, Geneva, 1990.

— the timely availability of findings compared with those of a large-scale prospective study.

The concomitant drawback to this analysis strategy was that no control could be exercised over the design of the original studies which, as with all secondary or meta-analyses, could prove problematic in interpreting the results. Two measures tended to minimize this problem: first, studies were selected on the basis of predetermined standards to ensure their validity and comparability (see Chapter 2); second, a detailed study protocol was provided to collaborators to encourage a uniform approach. Investigators were also asked to supply a copy of their data to WHO so that uniform preparations (including definitions and exclusions) were applied, and a common set of analyses was performed using the same statistical software. The individual study results were then subjected to a formal meta-analysis as reported below.

Project objectives

The objectives of this meta-analysis are:

— to test to what degree anthropometric measurements are useful and efficient in predicting maternal and child outcomes of pregnancy (including complications during pregnancy, labour and delivery, as well as postpartum) in different country settings;

— to determine the quantitative association of specific indicators and combinations of indicators and risk for mother and infant;

— to develop specific reference curves for maternal weight gain (or weight gain-for-height or arm circumference) for populations with different characteristics, as tools to monitor pregnancy in the community and home.

Outcomes investigated

Most studies concentrate on the infant outcomes (e.g., birth weight, survival, and perinatal or neonatal growth) and the majority of studies had information relating to one or more of these. This project seeks feasible predictors of both maternal and infant outcomes, so particular efforts were made to identify data sets that included pregnancy complications (e.g., assisted delivery, pre-eclampsia, cephalopelvic disproportion), as well as postpartum problems (e.g., haemorrhage). The outcomes listed in Table 1 were expected to be common to a number of national studies as they are routinely noted in a clinical setting. In fact it was found that only the items in italics were reported in a sufficient number of studies for investigation in this phase of the project. The remaining outcomes, and possibly others, will form part of the ongoing research as the data bank expands.

Core indicators

Kramer (*4*) provided a review of the many factors having a known or potential bearing on selected fetal outcomes, including genetic, constitutional, demographic, obstetric and nutritional variables. While information on these factors is important in a clinical setting, the present work focuses specifically on maternal nutrition. In defining a minimal set of such indicators, the constraints of service coverage, availability of proper equipment and the training level of the health worker provide an operational framework. Table 2 summarizes the indicators felt to be practicable for each combination. The column headings indicate the operational limitations by cross-classifying equipment availability (scales vs. no scales) with service coverage and worker training (service constraints). The row categories reflect the frequency of antenatal visits and hence the use of the measure-

Table 1: **List of maternal and fetal outcomes of interest**[a]

Stage	Outcomes/complications
Pregnancy	*Pre-eclampsia*[b]
	Eclampsia
Labour/delivery	*Prolonged labour*
	Assisted delivery (forceps/vacuum extraction)
	Cephalo-pelvic disproportion
	Caesarean section
Postpartum	*Postpartum haemorrhage*
	Maternal mortality
	Maternal anthropometry
Fetus	*Low birth weight*
	Intrauterine growth retardation
	Preterm birth
	Mortality: peri- and neonatal
Newborn	Anthropometric measures

[a] For purposes of both the analysis and the recommendations a distinction has been made between low birth weight (LBW) and intrauterine growth retardation (IUGR). The former is defined by WHO as a birth weight less than 2500 grams, and is very widely used as a recognized poor outcome for the infant, resulting in an elevated risk of morbidity and mortality. However, the LBW definition does not take account of the gestational age of the infant, whereas IUGR does. An infant is defined as IUGR if its birth weight is less than the 10th centile of a suitable weight-for-gestational age reference. This is felt to provide a clearer indication of the problem and avoid the confounding effect of birth weight with preterm birth. Data from Williams et al. (*5*) were used to establish a common fetal growth reference for purposes of the meta-analysis. For the secondary analysis, all investigators reported on LBW, but often employed a local definition of IUGR. IUGR is at present more often found in the scientific and research literature, while LBW continues as the most common measure of poor fetal outcome in the operational context worldwide. It was felt that a report on the analysis of LBW, IUGR, and preterm birth would be of special value.

[b] Items in italics were the only ones reported in a sufficient number of studies for investigation in this phase of the project.

Table 2: **Framework for maternal anthropometric indicator analysis**

Service delivery constraints:	Scales available (I) None	Scales available (II) Some	No scales available (III) None	No scales available (IV) Some
A	Early in pregnancy[a]	Late in pregnancy[a]	Early in pregnancy	Late in pregnancy
Single measurement				
SCREENING	— MUAC[b] — Height — Weight attained	— MUAC — Height — Weight attained	— MUAC — Height	— MUAC — Height
B	Throughout pregnancy	Late in pregnancy	Early in pregnancy	Not applicable
Multiple measurements				
SCREENING or MONITORING	Δ Weight[c] Δ MUAC Height	Δ Weight Δ MUAC Height	Δ MUAC	

[a] Access to the mother 'early in pregnancy' would imply contact during the 1st trimester or even pre-pregnancy. Access 'late in pregnancy' implies contact at around 30 weeks or later.

[b] Mid-upper-arm circumference.

[c] The symbol Δ is used to denote change in the measurement during pregnancy. Although listed in **B** as a potential indicator for use in monitoring, MUAC was found to change very little, if at all, during pregnancy for the data analysed. Height will not change during pregnancy (unless the mother is still physically maturing) and it may be conveniently recorded at any point of contact with the mother.

Notes on Table 2

(i) Service delivery constraints entail considerations of coverage, availability of appropriate equipment, quality of staff training, etc. The assumption is made that if coverage and quality are very limited, then service contact prior to pregnancy is unlikely and pre-pregnancy weight cannot be determined. Similarly multiple contacts with the mother are unlikely in such circumstances, so the assessment of gestational weight gain will not be possible.

(ii) In **A** and **B** above, it must be appreciated that the choice of study indicators does not imply that these are appropriate to detect 'responders' to any one of a number of possible interventions (e.g., dietary supplementation, or referral to a better equipped centre).

ment, i.e., for screening or monitoring. The cells list the measurements considered feasible under the combination of circumstances. To illustrate, if service constraints are poor and coverage is low (columns II and IV), it is likely that mothers may be seen only once before delivery and, that too, relatively late in pregnancy. In these circumstances, maternal height, arm circumference and, if scales are available, the attained weight are the only practical measurements (cells A II and A IV).[b] If there are fewer service constraints and service coverage is high, it is likely that contacts will occur on several occasions throughout pregnancy and multiple measurements are possible (cells B I and B III). The purpose is to report on the utility of the listed indicators (and combinations of these) in a way that reflects the structure of Table 2. This should permit the service provider to identify the circumstances pertaining locally and consider the corresponding options. Global experiences in relation to the current use of these core indicators are discussed in detail in the recent PAHO report (*1*) and are summarized in a WHO publication (*3*).

As is evident from Table 2, each indicator can potentially be measured at various times during pregnancy, depending on timing and frequency of contact with the health service. These service contacts may be conveniently categorized as pre-pregnancy, first antenatal visit (at whatever gestational age), and subsequent visits. Therefore, information may be obtained for a given indicator in the possible combinations shown in Table 3.

Project stages

(i) The protocol to assist investigators in the reanalysis of their data was developed at the World Health Organization between June and July 1990, and was subsequently reviewed and revised.

(ii) Some 55 investigators were identified and contacted (August to December 1990) and asked to provide a detailed description of their study for review by a WHO panel. The submissions received

[b] This is not to preclude the possibility of other circumferences (e.g., head and calf) or skinfold thicknesses, etc.; however, irrespective of merit, these are less commonly employed now and are not considered in this report.

Table 3: **Key indicators and time at which these may be measured**

Measurement	Frequency	Maternal indicator	Abbreviation
Height	Any time before or during pregnancy	1. Height	HT
Arm circumference	Pre-pregnancy and change during pregnancy	2. Mid-upper-arm circumference	MUAC
Weight	Pre-pregnancy and attained weight during pregnancy	3. Pre-pregnancy weight	WTpp
		4. Attained weight by month 5	WT/5
		5. Attained weight by month 7	WT/7
		6. Attained weight by month 9	WT/9
Weight gain	Weight change during pregnancy	7. Weight gain: month 5 to 7	WTg/5–7
		8. Weight gain: month 5 to 9	WTg/5–9
		9. Weight gain: month 7 to 9	WTg/7–9
		10. Weight gain: pre-pregnancy to month 5	WTg/pp–5
		11. Weight gain: pre-pregnancy to month 7	WTg/pp–7
		12. Weight gain: pre-pregnancy to month 9	WTg/pp–9
Body mass index (BMI)	Pre-pregnancy and attained BMI during pregnancy	13. Pre-pregnancy BMI	BMIpp
		14. Attained BMI by month 5	BMI/5
		15. Attained BMI by month 7	BMI/7
		16. Attained BMI by month 9	BMI/9
In mothers with low maternal height:			
Weight	Pre-pregnancy and attained weight during pregnancy	17. Pre-pregnancy weight	WTpp(HT)
		18. Attained weight by month 5	WT/5 (HT)
		19. Attained weight by month 7	WT/7(HT)
		20. Attained weight by month 9	WT/9(HT)
Weight gain	Weight change during pregnancy	21. Weight gain: month 5 to 7	WTg/5–7(HT)
		22. Weight gain: month 5 to 9	WTg/5–9(HT)
		23. Weight gain: month 7 to 9	WTg/7–9(HT)
		24. Weight gain: pre-pregnancy to month 5	WTg/pp–5(HT)
		25. Weight gain: pre-pregnancy to month 7	WTg/pp–7(HT)
		26. Weight gain: pre-pregnancy to month 9	WTg/pp–9(HT)
In mothers with low pre-pregnancy weight:			
Weight	Attained weight during pregnancy	27. Attained weight by month 5	WT/5(WT)
		28. Attained weight by month 7	WT/7(WT)
		29. Attained weight by month 9	WT/9(WT)
Weight gain	Weight change during pregnancy	30. Weight gain: month 5 to 7	WTg/5–7(WT)
		31. Weight gain: month 5 to 9	WTg/5–9 (WT)
		32. Weight gain: month 7 to 9	WTg/7–9(WT)
		33. Weight gain: pre-pregnancy to month 5	WTg/pp–5(WT)
		34. Weight gain: pre-pregnancy to month 7	WTg/pp–7(WT)
		35. Weight gain: pre-pregnancy to month 9	WTg/pp–9(WT)

were used to judge if the study was suitable for inclusion in this project. Several previously agreed considerations determined this, including study design and data quality. A number of the prerequisites are discussed in the study protocol, and are commented upon in Chapter 2.

(iii) Grants were awarded to the selected collaborators between November 1990 and June 1991. In all, 8 studies were supported at this stage by WHO; a further 11 studies had previously been supported by WHO or its Regional Offices. Finally, secondary analysis of the remaining studies was undertaken by

Table 4: **Studies available for meta-analysis as of the end of December 1991**

Country	Abbreviation	Study
Argentina	ARG	Rosario
Botswana	BOT	WHO Hypertensive Disorders of Pregnancy study
China	CHI	WHO Hypertensive Disorders of Pregnancy study
Colombia	COL	Valle del Cauca Perinatal study
Cuba	CUB	Cuban Risk Approach Study
Gambia	GAM	Keneba Supplementation study (MRC–Dunn Nutrition Unit, Cambridge)
Guatemala	GUA	'Oriente' study—INCAP
India (Pune)	IN(P)	WHO/SEARO Multicentre study on risk for low birth weight
India (Hyderabad)	IN(H)	NIN Hyderabad Anaemia Risk Study
Indonesia	INO	Bogor study on risk of low birth weight
Ireland	IRE	Rotunda study, Dublin
Lesotho	LES	WHO Hypertensive Disorders of Pregnancy study
Malawi	MAL	Malawi Maternal & Child Nutrition Study
Myanmar	MYN	WHO Hypertensive Disorders of Pregnancy study
Nigeria	NIG	Pregnancy risk study
Nepal (Rural)	N(R)	WHO/SEARO Multicentre study on risk for low birth weight
Nepal (Urban)	N(U)	WHO/SEARO Multicentre study on risk for low birth weight
Sri Lanka	SL	WHO/SEARO Multicentre study on risk for low birth weight
Thailand	THA	WHO Hypertensive Disorders of Pregnancy study
United Kingdom	UK	Aberdeen, Scotland
USA (CDC–Black)	US/CDC(B)	Pregnancy Nutrition Surveillance System (Centers for Disease Control)
USA (CDC–Hispanic)	US/CDC(H)	Pregnancy Nutrition Surveillance System (Centers for Disease Control)
USA (CDC–White)	US/CDC(W)	Pregnancy Nutrition Surveillance System (Centers for Disease Control)
USA (NCPP–Black)	US/NCPP(B)	National Collaborative Perinatal Project
Vietnam	VIE	WHO Hypertensive Disorders of Pregnancy study

the relevant national or international agencies. All together these data sets represent information on over 111 000 births in 25 studies from 20 countries.

(iv) Following completion of the re-analysis of the various data sets by collaborators, individual study reports were prepared by the investigators and submitted to WHO (March 1991 through February 1992). Concurrent with this phase, investigators were requested to provide their data for a joint analysis by WHO. This enabled the testing and statistical control of possible cross-study confounding factors (by meta-analysis techniques, see Chapter 4), which could account for some of the anticipated differences in performance of individual or multiple predictive indicators. Extensive checking, cleaning and preparation for the joint analysis of the multiple data sets began around the middle of 1991 and continued through December 1991. Preliminary analyses were undertaken in preparation for a meeting of the collaborators that was held on 17–19 February 1992 in Cali, Colombia. This meeting provided an opportunity for the investigators to report on the re-analysis of their data, and to finalize plans for the meta-analysis and the preparation and content of the present report.

A list of the data sets by country of origin is given in Table 4. Abbreviations for study names used throughout the text are also listed in this Table.

Structure of this presentation

The main results of the meta-analysis are presented for three infant and three maternal outcomes in Chapters 5 and 6, respectively. Within each section selected anthropometric indicators are reported, with results for all indicators being summarized at the beginning of each chapter. The decision to include a large amount of detail on the meta-analysis was dictated by two considerations. First, meta-analysis is a relatively recent set of methodologies and therefore remains debatable; and the subject is still developing at a rapid pace (*6*). The techniques employed in the present study were first published as recently as 1992 (*7*). Consequently, it is recommended that all meta-analyses be as fully documented as possible so as to enable a proper assessment of the strength and

limitations of the work. The potential application of the results reported here requires compliance with that recommendation. Given the stated objective of this project, i.e., not only to ascertain the degree of association between various indicators and pregnancy outcomes, but also to offer some guidance on possible choices between these indicators, a second reason for the level of detail presented is to enable the findings to be assessed in relation to the reader's own context of interest—including geographic area. Possible differences in findings, and the reasons for these, may need to be accounted for before any recommendations are considered for local adoption. Nevertheless, it is certainly appreciated that for some readers a simple and direct summary of the findings is all that is required, and this has been achieved by dividing the report into results sections (for fetal and maternal outcomes, see Chapters 5 and 6, respectively), and conclusions and recommendations (Chapter 8). A section of technical notes (Chapter 9) enables various methodological issues to be addressed without burdening the main text, and this is followed by various appendices where more detailed information can be found.