1 **Meta-analysis using Individual Participant Data from randomised trials: Opportunities**

2 **and Limitations created by access to raw data**

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25   **Abstract**

26   Meta-analysis based on Individual Participant Data (IPD), often described as the 'gold

27   standard' for effectiveness evidence synthesis, is increasingly being deployed despite being

28   more resource intensive than collating study-level results. Its professed virtues include the

29   ability to incorporate unreported data and to standardise variables and their definitions across

30   trials. In reality, the unreported data, even though present in shared datasets might still not be

31   usable in the analysis. The characteristics of trial participants and their outcomes may be too

32   diversely captured for harmonisation, and too time-and-resource-consuming to standardise.

33   Embarking on an IPD meta-analysis can lead to unanticipated challenges which ought to be

34   handled with pragmatism. The aim of this article is to discuss the opportunities created by

35   access to IPD and the practical limitations placed on such meta-analyses, using an

36   international IPD meta-analysis of trials on the effect of lifestyle interventions in pregnancy

37   as an exemplar. Despite the increasing uptake of IPD meta-analysis, they encounter old

38   problems shared by other research methods. When embarking on IPD meta-analysis, it is

39   essential to evaluate the trade-offs between the ambitions, and what is achievable due to

40   constraints imposed by the condition of collected IPD. Furthermore, incorporation of

41   aggregate data from trials where IPD was not available should be a mandatory sensitivity

42   analysis that makes the evidence synthesis up-to-date.

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44   **Word count**: 199/250

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Introduction

Meta-analysis using Individual Participant Data (IPD) is becoming increasingly popular despite being a laborious and resource-intensive method of evidence synthesis compared to a standard review using study-level data.[1] It has the potential to overcome limitations of meta-analyses based on published data through access to raw trial data[1-4] such as standardisation of analysis methods and data across trials[1,5] (Table 1). Access to IPD can facilitate integrity checks and intention to treat analysis by imputing for missing data. Collation of rarely reported variables for the key outcomes can result in greater precision of the intervention effect and address the problem of selective reporting.[1]

Existing methodological literature focuses mainly on cost, team's expertise and management of the collaboration.[3] Yet, not much is available on practical challenges associated with data harmonisation and their consequences for IPD meta-analyses. The aim of this article is to discuss the some of the opportunities created by access to IPD and the limitations of meta-analysis using IPD as indicated in Table 1. We use the i-WIP IPD meta-analysis of 36 trials (12,526 participants from 16 countries; 50 investigators) on the effect of diet and physical activity based interventions in pregnancy[6] as an exemplar (Appendix 1).

Standardisation of data across trials

Access to IPD should create a unique opportunity to unify all essential data. This is true assuming that collected data can be brought to the same format without losing their value. Routinely collected data such as age, weight or height tend to be captured as real values making them relatively easy to harmonise. Participant characteristics recorded in other formats or those less routinely collected can be much more challenging to standardize. One of the subgroups of interest in the project was maternal ethnic origin[7]. The characteristic was

71 available for 47% (17/36) trials of which one differentiated only between indigenous and

72 non-indigenous women, four classified women only as Caucasian or non-Caucasian, and

73 eight declared to include only Caucasians or not recognise "ethnicity" in their country. The

74 characteristic was grouped into six categories (Caucasian, Asian, Afro-Caribbean, Central

75 and South American, Middle Eastern, other and unknown) but due to a low proportion of

76 women from groups other than Caucasian (>80% of included women) in the analysis of

77 differential effects of intervention by ethnic origin the characteristic was used in the binary

78 format (Caucasian/non-Caucasian).[6]

79

80 Harmonisation of outcome definitions faced similar challenges. While some definitions are

81 relatively easy to bring to a common format across the trials e.g. preterm birth,

82 standardisation of others was simply not feasible. The task can be even more daunting when

83 there is no consensus on classification methods, or the definitions changed over the years.

84 Despite access to IPD, direct communication with the research teams and the idea

85 endorsement by the members of the i-WIP collaborative group, standardisation of outcomes

86 such as gestational diabetes (GDM) or caesarean section turned out to be unachievable within

87 the study funding time. Diagnosis of GDM was based on a broad range of guidelines that

88 followed algorithms that did not always overlap with each other. We have made an attempt

89 to standardise the definitions of GDM and collected the blood test measurements used to

90 diagnosis the condition. However, the variability in glucose loads (50, 75 or 100 grammes)

91 and tests' timing (fasting, 1 hour or 2 hours) lead us to abandon this task and acknowledge

92 the variability in the outcome definition as a limitation. The variety of GDM definitions and

93 the blood test measures, as well as the coding of participants ethnic origin in the trials with

94 diet and/or physical activity in pregnancy, is presented in Appendix 2.

95

Unreported outcomes

Selective reporting of intervention effects depending on statistical significance is one of the most important sources of bias affecting clinical trials.[8-11] Despite clear guidance on reporting of outcomes in the trial reports[12], the problem persists, having a serious impact on the meta-analysis. In combination with variation in choice of trial outcomes[13], they are contributing to the serious waste of research efforts. More frequent reporting of statistically significant results can lead to a potential overestimation of underlying treatment effects in a meta-analysis when using data extracted from trial publications. IPD meta-analysis has the potential to address this problem through facilitating analysis of core outcome sets[14], if available in trial datasets but not reported in publications.

Access to individual records should increase the number of trials included in the analysis and enhance the quality of outcome data. However, the benefits may not always be substantial. In the i-WIP project, the number of trials with the outcomes of interest was higher through access to IPD in comparison to data extracted from publications (Appendix 3). Additionally, use of the raw data to generate outcomes not considered in original trials (e.g. use of gestational age at delivery to define the occurrence of prematurity) may lead to a substantial increase in the number of the trial that can be incorporated into the meta-analysis (Table 2). Even so, the presence of data in the dataset did not always allow to incorporate a given dataset in the statistical analysis. Too few events (e.g. stillbirths) and lack of all measures (baseline and final for weight gain) prevented trial inclusion. Still, in the example incorporation of trials with previously unavailable outcome data changed the value of the effect estimate by more than 10% in three outcomes and its statistical significance in one (Table 2).

121 The addition of unreported data may or may not lead to a change in funnel plot asymmetry. In

122 the example, incorporation of unpublished outcomes in the meta-analysis for admission to

123 neonatal intensive care unit has not revealed any potential bias. Similarly, for small for

124 gestational age infant where outcome data were generated uing raw data if the outcome was

125 not considered in original trials (Table 2). For continuous outcomes (gestational weight gain

126 in the example) the change in the plot asymmetry might also occur due to the standardisation

127 of the analysis methods rather than incorporation of unreported data (Figure 1).

128

129 **Role of IPD meta-analysis in dynamic research areas**

130 The authors of guidance on the appraisal of IPD meta-analyses of randomised trials advocate

131 checking for the proportion of trials from which IPD was obtained.[5] A recent study showed

132 that only 25% of evaluated IPD meta-analyses obtained 100% of identified trial

133 data.[15]Acquisition of all eligible trials can be challenging for numerous reasons, with

134 uncooperative trial investigators mentioned most commonly.[5] IPD meta-analysis is a lengthy

135 and resource intensive process which can also decrease the chance of complying with the

136 above mentioned recommendation.

137

138 Since the publication of the systematic review that laid the grounds for the IPD meta-analysis

139 we used as an example[16], there has been a significant increase in the number of trials

140 evaluating the effects of diet and/or physical activity based interventions in pregnancy.

141 Between the end of data acquisition in June 2015 to February 2017 findings from additional

142 45 trials have been published (Figure 2) making achieving the goal of being up to date and

143 obtaining the majority of IPD virtually impossible.[17] In combination with the trials for which

144 IPD was sought but not obtained, the number of trials outside the IPD meta-analysis (non-

145 IPD studies) constituted 65% of trials (67/103 trials) and 51% of women randomised to all

146 eligible trials (12,960/25,486). The meta-analysis combining IPD with non-IPD studies,

147 showed a stronger overall effect of interventions in reduction of gestational weight gain and a

148 significant reduction of odds for GDM then one using only IPD.[17]

149

150 **Summary**

151 Despite the advantages of meta-analysis using IPD, the method encounters problems faced by

152 other research methods such as uncooperative investigators or incompleteness of records. The

153 IPD meta-analysis is a resource-demanding approach to evidence synthesis and requires a

154 thorough evaluation of what is achievable. It might be that we will need to accept that some

155 primary research is not usable for evidence synthesis. Mapping of definitions and additional

156 data that could help to standardise the outcome across the trials may not tackle all the issues,

157 but will facilitate the smoother conduct of IPD meta-analyses. The efforts associated with

158 obtaining IPD and its harmonisation need to be balanced by the potential gains achievable

159 through a complex and profound statistical analysis. Prospectively designed IPD meta-

160 analyses have the potential to overcome some of the challenges described in this article as

161 they tend to collect data in a preagreed format[18]. Promotion of consensus on the research

162 standards with regards to outcome definitions, capturing of participants' characteristics, and

163 effective ways implementing them in the trials should help to reduce the potential research

164 waste. Finally, putting the findings of IPD meta-analysis into a context of the totality of

165 evidence is paramount for the validity of results. (ref) Currently guidelines recommend

166 adding non-IPD studies to IPD meta-analysis when a substantial proportion of trials IPD was

167 not obtained at the beginning of the project. Additionally, in some areas of medical research

168 the amount of evidence generated annually makes it difficult to stay up to date while

169 conducting IPD meta-analysis. Therefore, adding newly published trials is as important as

170 incorporating the not shared ones.

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Contributors

ER wrote the initial draft of the manuscript and all subsequent drafts after critical review by

JZ, NM and KSK. ER is a guarantor for the manuscript.

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Tables

Table 1 Purported theoretical advantages of Individual Participant Data (IPD) meta-analysis

of clinical trials and practical limitations in achieving them

Table 2 Meta-analysis of trials with diet and/or physical activity based interventions in

pregnancy with available individual participant data (IPD)

Figures

Figure 1 Comparison of funnel plots between meta-analyses using published and individual

participant data (IPD)

Figure 2 Number of randomised controlled trials with diet and/or physical activity based

interventions provided antenatally

Appendix 1 International Weight management in Pregnancy (i-WIP) Individual Participant

Data (IPD) meta-analysis

194   **Appendix 2** Examples of data coding variability in randomised trials with diet and/or

195   physical activity in pregnancy included in i-WIP IPD meta-analysis

196   **Appendix 3** Number of trials and corresponding datasets containing and contributing

197   outcome data to meta-analysis

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