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Does measurement technique explain the mismatch between European head size and WHO charts?

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ABSTRACT

Objective: To test whether different measuring techniques produce systematic differences in head size that could explain the large head circumferences found in Northern European children compared to the WHO standard

Design: Cross sectional observational study

Setting: Glasgow, United Kingdom

Patients:

Study one: 68 healthy children aged 0.4 to 18 months from mother and baby groups and a medical students teaching session. Study two: 81 children aged 0.4 to 25 months from hospital wards and neonatal follow-up clinics.

Interventions:

Study one: heads measured with plastic tape using both the WHO tight and UK loose technique. Study two: heads measured using WHO research technique and a metal measuring tape and compared to routinely acquired measurements.

Main outcome measures: Mean difference in head Z scores using WHO standard between the two methods

Results: The tight technique resulted in a mean (95% CI) Z score difference of 0.41 (0.27 to 0.54, p<0.001) in study one and 0.44 (0.36 to 0.53, p<0.001) in study two. However the mean WHO measurements in the healthy infants still produced a mean Z score that was 2/3 of a centile space (0.54 SD (0.28 to 0.79) P<0.001) above the 50th centile.

Conclusions: The WHO measurement techniques produced significantly lower measures of head size, but average healthy Scottish children still had larger heads than the WHO standard using this method.

What is already known on this topic

- Studies in European infants have shown their average head size to be above the WHO 75th centile, rather than on the 50th centile, as would be expected.
- It has been suggested that this may reflect different measurement techniques

What this study adds

- Using the WHO measurement method produced smaller measurements than the standard method in use in the UK and USA
- These average measurements were still 2/3 of centile space higher than the 50th centile.

BACKGROUND

Accurate anthropometric measurements, compared to reliable reference ranges, are important for both disease monitoring and child public health. In the UK, parents of all newborn children are issued with a Personal Child Health Record, which includes growth charts into which health professionals are encouraged to input measurements when they review a child. Children with poor height and weight gain may be brought to specialist paediatric attention as a result of abnormal routinely collected measurements. There is increasing interest in the diagnosis of congenital microcephaly in view of its association with Zika virus [1], but accurate case identification depends on valid norms for head circumference.

New UK-WHO growth charts were launched in 2009. They incorporate the WHO 2006 Growth Standards from age 2 weeks to 4-years[2] combined with recalculated birth data from the British 1990 growth reference [3]. The charts include UK-WHO head circumference standards published in April 2007 between 2-weeks and 2-years of age [4]. Although UK children show a good fit to the WHO 2006 standard for length [5], recent research has found that head circumferences of British children are large relative to the UK-WHO standard [6]. Norwegian and Belgian children also have large heads compared to the WHO standard [7]. The difference is equivalent to more than 1 cm at age one year, which places average UK children one SD above the 50th centile, above the 75th centile. This greatly increases the proportion of children with apparent macrocephaly, reduces the proportion with apparent microcephaly and thus makes the charts potentially misleading.

It has been suggested that this difference in fit to the standard arises from differing measurement techniques. The WHO [8]technique specifies that the tape should be drawn tight, and that the mean of three measurements should be taken as the true head circumference. In contrast, standard UK and US practice is to apply the tape measure closely round the head, but not pull it tight and to measure the maximum circumference of the head. It is not clear whether differences in measurement technique are sufficient to explain the difference observed, but if they are, they might signal the need to recommend the routine application of the WHO technique in the UK. However, if the difference between UK measurements and WHO standards is not explained by differences in technique, this might suggest that the UK should be using different standards. We therefore set out to test whether 1/ different measuring techniques produce systematic difference in head size and 2/ whether using the WHO research technique will result in an acceptable fit of healthy UK children's heads to the WHO standard.

METHOD

We undertook two rounds of data collection. The first study simply compared the WHO method to the UK method using the same plastic tape in healthy children. In the second study the WHO method was used with the recommended metal tape, collected in research conditions, and compared to routinely collected head circumference measures using standard UK procedures.

Study one involved two separate rounds of data collection, obtained in two different settings. In the first round (round A) parents were recruited via breastfeeding support groups, baby and toddler playgroups and social networks in Edinburgh and Glasgow UK, to participate both in this measurement study and a survey on infant eating behaviour. Researchers (SL, FB) then attended group meetings or set up special research sessions to measure the infants' heads. Each of the two researchers (a medical student and a children's nurse) measured and recorded each child's head circumference twice, blinded to the other's measurements, with a plastic non-stretchable head circumference tape (Child Growth Foundation) using one of the following methods:

1. Tape wrapped round the head and ends of tape overlaid and measurement read off (Loose method, UK/US)

2. Tape drawn round tightly and measurement read off (Tight method, WHO)

In the second round (B), mothers attending a breast feeding workshop for medical students were invited in advance to participate and their baby was measured in the hour before the workshop. There were six researchers (four medical students, a consultant paediatrician and a nurse) working in pairs. Each child was measured by one pair of researchers, each using either the loose or tight method alternately, blinded to the other's measurements, with three measures taken and recorded by each.

For these studies ethical approval was obtained from the Glasgow University MVLS College Ethics Committee and all parents signed a consent form.

Study two recruited children under the age of two years from the neonatology follow-up clinics at Princess Royal Maternity Hospital, Glasgow and from inpatients at the Royal Hospital for Children, Glasgow. Ethical approval for this study was obtained from the NHS West Midlands-Black Country Research Ethics Committee. For this study the WHO recommended metal tape (Chasmors) was used for the WHO measuring method. Three researchers were trained in the WHO method and underwent similar standardisation protocols as those in the Multicentre Growth Reference study (MGRS), until the error between measurements was less than 5.0mm, the maximum allowable difference used in the MGRS in order to minimise inter-measurer error[8]. The WHO technique requires a head measurer and someone to assist in positioning of the tape.

For children attending neonatology follow-up clinics, after signing a consent form, a medical student (MB) measured the children's heads three times using the WHO method. During the consultation, the clinic doctors who were experienced in measuring head circumference in clinical practice, measured the child's head using their own standard practice, and this measurement was retrieved after the consultation. These doctors received no additional briefing or training in head measurement technique. For inpatients, once parents had consented, one of the two other researchers measured the child's head three times using the WHO method. The child's head was then also measured by one junior doctor using the UK method again with no additional briefing or training in head measurement technique. All measurers were blinded to the other measurer's results. A measuring assistant was present for all of the ward-based WHO measurements, but this was not always possible in busy clinics.

Analysis and power

The mean of the two or three values per child for each method was calculated as well as largest value for each. All measurements were converted into Z scores compared to the WHO standard. To detect a difference of the size already observed between UK infants and the WHO standard (1 SD)[6], 15 subjects would be required, but in order to detect a difference of half that size we calculated that 65 subjects would be needed. After the first round of data collection, the aim was to recruit at least 60 patients for the sample so that, with the earlier data, the sample would be large enough to detect a difference of 0.33 SDS.

RESULTS

In study one a total of 69 children’s heads were measured using both tight and loose techniques. In round A 31 babies median (range) age 7.03 (0.4 – 13) months were each measured by 2 researchers over a 6 week period. In round B 38 babies aged 6.25 (1.6 - 18) months were measured in one afternoon by 6 researchers. The overall findings from study one were that the mean loose measurements were a mean (95% CI) 0.30 (0.17 to 0.43) Z scores greater than the mean tight measurements, whilst the largest loose measurements were 0.41 (0.27 to 0.54) Z scores greater than mean tight measurements (Table 1).

Table 1: Head circumferences (cm) and Z scores compared to WHO standard for each method for study one

Values are Mean (SD) Head circumference (cm) and Z scores

Raw data (cm)	Tight average (1)	Loose average (2)	Largest loose (3)	Difference 2 - 1	P[1]	Difference 3-1	P[1]
Round A N=69	43.0 (3.1)	43.2 (3.0)	43.3 (3.0)	0.19 (0.77)	0.18	0.26 (0.77)	.07
Round B N=81	43.4 (2.8)	44.1 (2.9)	44.3 (2.9)	0.58 (0.70)	<0.001	0.76 (0.73)	<0.001
Pooled N=150	43.2 (3.0)	43.7 (2.9)	43.8 (2.9)	0.41 (0.75)	<0.001	0.53 (0.79)	<0.001
Z scores							
Round A	0.60 (1.1)	0.77 (1.0)	0.82 (1.1)	0.17 (0.60)	0.13	0.23 (0.60)	0.048
Round B	0.49 (1.0)	0.94 (1.1)	1.08 (1.1)	0.41 (0.45)	<0.001	0.55 (0.49)	<0.001
Pooled	0.54 (1.0)	0.86 (1.0)	0.97 (1.1)	0.30 (0.53)	<0.001	0.41 (0.56)	<0.001

[1] one sample t-test

Although using the tight method produced lower values than the loose method, the mean tight value remained 0.54 SD (0.28 to 0.79) P<0.001) above the WHO reference mean, just below the 75th centile (See figure 1).

In study two a total of 81 children were recruited and measured: 51 patients at neonatal follow-up clinics and 30 inpatients, of whom 41% (33) were female and 52% (42) were born before 37 weeks. The median (range) age of the children was 4.89 (0.37to 24.2) months. One child was older than two years but was included as the gestationally corrected age was under two. For the routine measures 70 (86%) measurers specified how many measures they took and how they summarised them; of these 24 (34.3%) only took one measure, 22 (31.4%) took the largest of two measures and 23 (32.9%) took an average of 2 or 3 measures. Overall the findings from study two were that the routine measures were mean (95% CI) 0.44 (0.36 to 0.53, p<0.001) Z scores greater than the mean WHO measures. There were no significant differences between location, term versus preterm, between different WHO measurers or the different routine measuring approaches (Table 2 and figure 2).

Table 2: Head circumferences (cm) and Z scores compared to WHO standard for each method for study two, broken down by setting, gestation and measurer

Values are Mean (SD) Head circumference (cm) and Z scoresAll	Number	WHO average	Routine	Difference between routine and WHO	P
Raw data (cm)	81	40.8 (4.6)	41.3 (4.6)	0.56 (0.49)	<0.001[1]
Z scores	81	-0.02 (1.4)	0.43 (1.4)	0.44 (0.38)	<0.001[1]
Gestation					
Preterm	42	0.08 (1.3)	0.52 (1.2)	0.44 (0.40)	
Term	39	-0.12 (1.4)	0.32 (1.5)	0.44 (0.36)	1.0[2]
Setting					
Clinic	51	0.28 (1.2)	0.76 (1.2)	0.48 (0.38)	
In patient	30	-0.52 (1.5)	-0.14 (1.5)	0.38 (0.38)	0.3[2]
WHO measurers					
1	51	0.28 (1.2)	0.76 (1.2)	0.48 (0.38)	
2	17	-0.24 (1.4)	0.27 (1.5)	0.50 (0.35)	
3	13	-0.90 (1.5)	-0.67 (1.4)	0.44 (0.38)	0.08[3]
Routine method					
One measure only	24	0.24	0.71	0.46	
Average of two measures[4]	24	-0.33	0.03	0.36	
Largest of two measures	22	-0.08	0.38	0.46	0.6[3]

[1]one sample t-test

[2]t-test for average difference between routine and WHO in each group

[3]ANOVA

[4]Includes one child with average of 3

DISCUSSION

The results from our two studies demonstrate that whilst variations in measurement technique account for around half of the difference between routine UK head circumference measurements and the WHO growth standard, they fail to explain all of this difference. The strength of study one was that the infants were recruited from a healthy, largely breastfed population. In view of the good fit for length in UK children[5] and that both the study group and the standard are based on breastfed infants, we would expect the mean of these children's head circumferences to be close to the WHO 50th centile. However, no matter which methodology we used for head circumference measurement, the values were all significantly larger than the WHO reference standard. Taking the mean of two tight measurements produced an average head circumference that was just over half a centile space smaller than taking the largest of two loose measurements, but this value was still 2/3 of a centile space above the WHO 50th centile. Another strength of study one is that all measurers used both tight and loose techniques of measurement, so differences cannot be explained by differences in any individual measurer's technique. Two potential criticisms of study one however are that we did not use the official WHO recommended metal tape for the tight measurements, and that the loose measurements were collected within an experimental setting and therefore may not accurately represent routinely collected measurements. We sought to answer both of these criticisms through study two, where all the WHO measurers used the exact technique described by the WHO [8]. Measurements were collected in a clinical setting in order that we could obtain true routinely collected head circumference values to compare against the WHO method of measurement. Because the participating children in study two were either hospital inpatients or neonatal follow-up cases, we did not expect their head circumferences to be reflective of the healthy population. Indeed the mean head circumference in study two was 0.017 Z scores *below* the WHO reference mean.

In study two the differences we observed between the routinely collected head circumference values and the values taken using WHO technique were of the same order of magnitude to those we saw between the tight and loose techniques in study one and this suggests that the loose technique used in study one closely represents the routine technique used in clinical practice, and that the tight technique used in study one also closely represents the WHO technique, even though a plastic rather than metal tape was used.

A further strength of study two was that we checked for inter observer variation and found only modest variation which was not statistically significant.

Previous studies have found that European infants have mean head circumferences of around 1.0 SD above the WHO reference mean by age 12 months[6 7]. Here we have shown that only half of this observed difference may be accounted for by variation in measuring technique. Thus it seems likely that there are in fact intrinsic differences in head shape in Northern Europeans compared to those regions that were used to set the WHO standards. A recent systematic review of data from 55 different countries or ethnic groups found substantial regional variation in head size, with UK head circumferences being the largest of the 15 European countries included, and one of the largest worldwide [9].

These results also raise important questions about the ideal head measuring technique. The measured differences observed were very small, on average around 0.5 cm, but to put this in context, a difference of this size is about the double the technical error of measurement (TEM)[1] found for the WHO growth chart measuring teams[10] and is equivalent to more than half a centile space on the WHO chart. Given that variation in measurement technique can produce such significant differences, it seems important to encourage a more consistent approach to head circumference measurement. Our recent paper found that most extreme measures and shifts in head size were not replicated at later measures, suggesting that inter-measurer variability plays a major role in such aberrations[11]. Ideally health care professionals should be provided with clear guidance as to what type of tape to use, how tight to draw the tape, and which value (mean or maximum) to take, as these difference could be meaningful

[1]The value which for one true head size describes the bound within which 70% of all measured values will lie

if different people measuring the same child used different techniques, or if different staff groups or institutions used different approaches.

It seems clear that the conventional practice of using the maximum circumference is likely to introduce positive bias. Meanwhile the tight approach has the risk that, as the tape is drawn tighter it may slide above or below the maximum circumference on the other side of the head from the measurer. This is probably why the WHO specify that there should be a second measurer, though this is not usually feasible in a busy clinical setting. Possibly the compromise should be to use the average of three successive tight measures tape, as long as all three are within the range specified by the WHO[8]. The WHO recommended metal tape used in study two was remarkably hard to source and unlikely to be available in most clinical settings, but the tight method is not feasible using the paper tapes commonly provided in UK clinics. A more robust, non-distensible plastic tape, as used in round one, seems a sensible compromise.

CONCLUSIONS

Establishing and teaching a consistent and robust measurement technique based on WHO procedures is needed to reduce unnecessary variability in estimates of head circumference. However, even when replicating the full WHO measurement techniques, British children on average have larger heads than the WHO standard, suggesting that the WHO head standard is not suitable for use in the UK.

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Contributors

CW conceived the study, was a measurer in study one, undertook the analysis and drafted the paper. SL planned and ran the data collection for study one and was a measurer. MB planned and ran study two and collected the outpatient measurements. JS helped plan study two and draft the paper. All authors have seen and approved the draft paper.

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Ethical approval

Study one: Glasgow University MVLS College Ethics Committee.

Study two: NHS West Midlands - Black Country Research Ethics Committee 15/WM/0474

Competing interests

CW led the group that implemented the WHO head standard into growth charts in the United Kingdom. None of the other authors have any competing interests.

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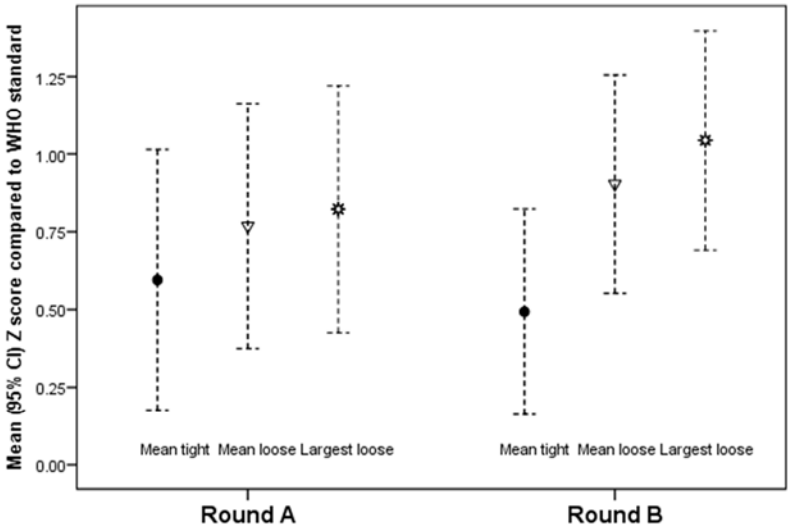
LEGENDS TO FIGURES

Figure 1: Mean (95% confidence intervals) Z scores in Study one, depending on measurement type.

Figure 2: Mean difference (95% confidence intervals) in Z scores between the two methods in study one and study two

Figure 1



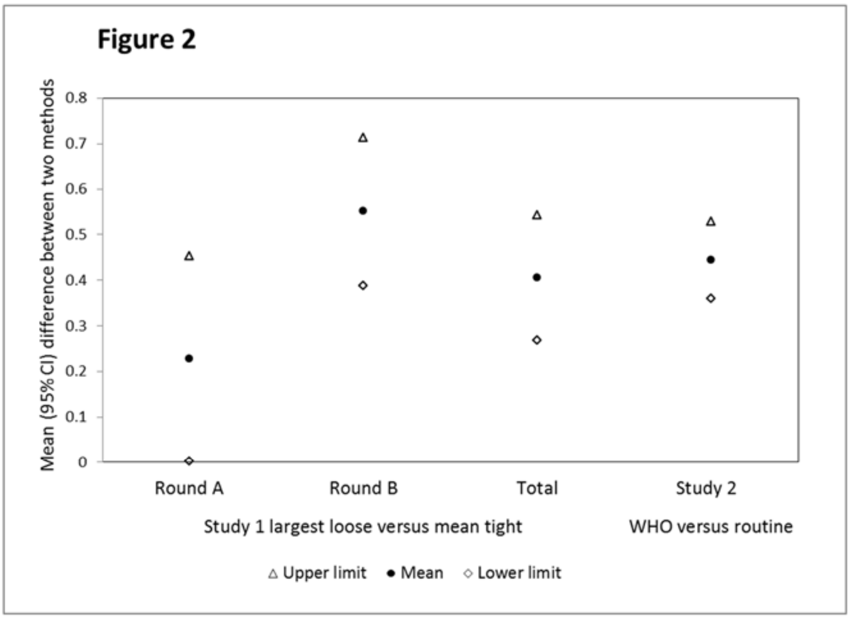


Figure 2
Mean (95% CI) difference between two methods
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Round A
Round B
Total
Study 2
Study 1 largest loose versus mean tight
WHO versus routine
Upper limit
Mean
Lower limit

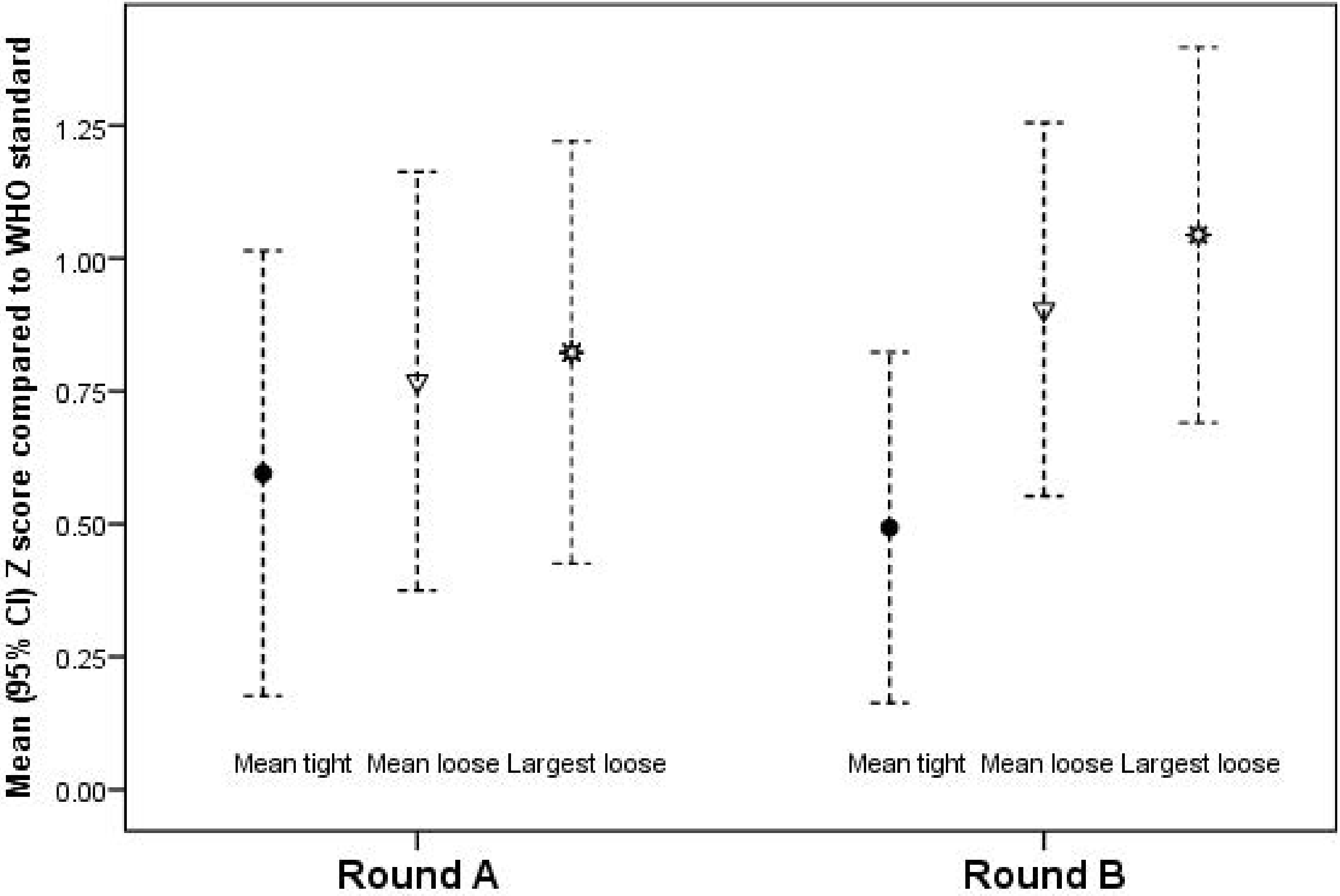
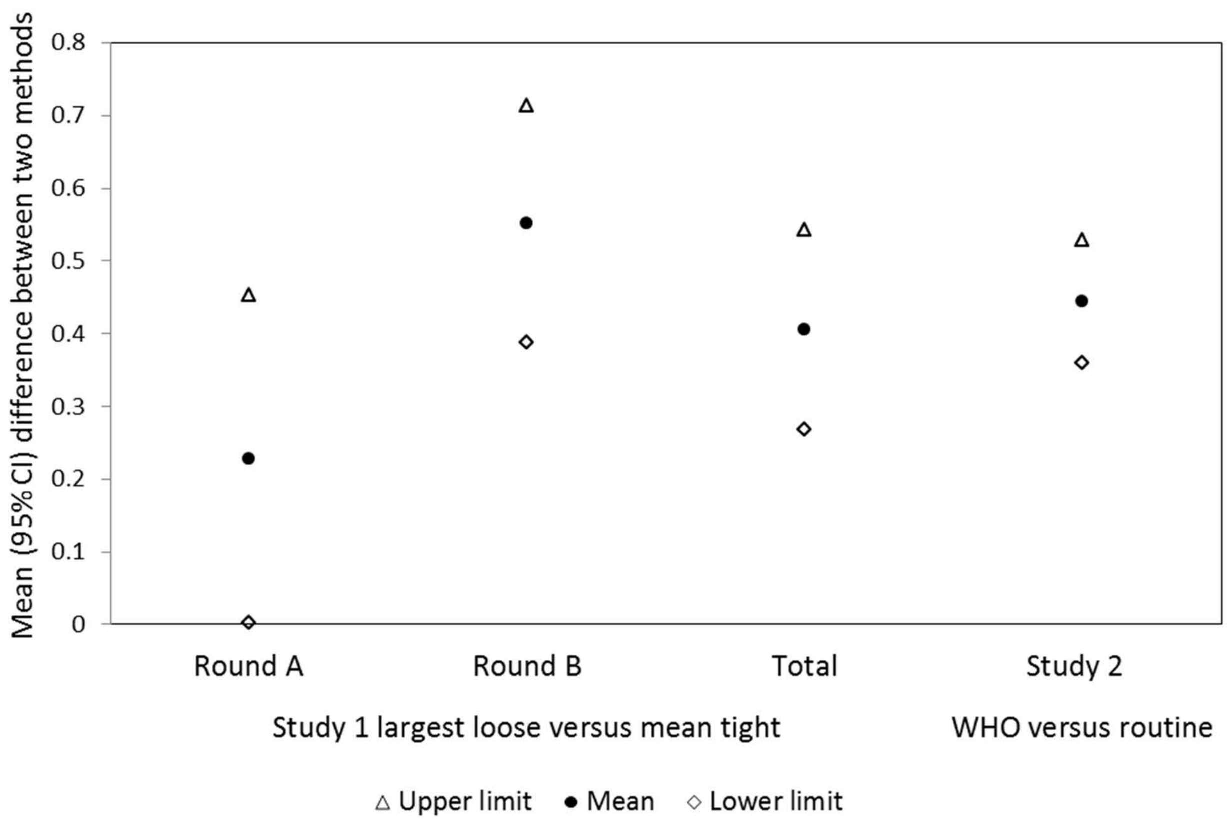

Mean (95% CI) Z score compared to WHO standard
1.25
1.00
0.75
0.50
0.25
0.00
Mean tight
Mean loose
Largest loose
Mean tight
Mean loose
Largest loose
Round A
Round B

Figure 2


Mean (95% CI) difference between two methods
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Round A
Round B
Total
Study 2
Study 1 largest loose versus mean tight
WHO versus routine
△ Upper limit ● Mean ◇ Lower limit