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10.4103/jfcm.jfcm_337_23

# Significant differences in the length and weight measurements of Jordanian infants compared to the World Health Organization 2006 growth standards

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**Abstract:**

**BACKGROUND:** In 2006, the World Health Organization (WHO) introduced new growth standards based on data derived globally from optimally nourished breastfed infants. The aim of this study was to assess the effects of implementing WHO growth standards on the growth patterns of Jordanian infants. In addition, it was to ascertain the necessity of establishing country-specific growth standards and charts tailored to Jordanian infants.

**MATERIALS AND METHODS:** The data of 102,846 infants (50.1% boys, 49.9% girls) aged 0–24 months, from 115 primary healthcare centers across the country were retrieved from a National E-health Program. Weight and length measurements were analyzed, and age- and sex-specific *z*-scores were calculated relative to the WHO growth standards. Data was analyzed using SPSS version 26. Mann–Whitney U test was performed to determine significant differences between the measurements for boys and girls in terms of age, length, and weight.

**RESULTS:** Jordanian infants exhibited significantly shorter length-for-age measurements than WHO standards with mean *z*-scores of −0.56 and −0.38, for boys and girls, respectively. Weight-for-age measurements showed a good fit and were comparable to the WHO growth standards for boys (mean *z* score = −0.05) and girls (mean *z* score = 0.04). Notably, Jordanian infants displayed higher weight-for-length measurements, with mean *z*-scores of 0.51 for boys and 0.47 for girls.

**CONCLUSION:** The availability of Jordanian-specific growth standards will improve the accuracy of assessing infant growth and enhance the monitoring and evaluation of their health and development.

**Keywords:**

Growth standards, Jordanian infants, length-for-age, National growth charts, weight-for-age, weight-for-length

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**Received:** 28-11-2023
**Revised:** 31-01-2024
**Accepted:** 14-02-2024
**Published:** 15-04-2024

## Introduction

The measurement of growth parameters in a child or group of children is one of the most sensitive and commonly used indicators of child health.[1] Growth references are extensively utilized and serve as extremely valuable tools for evaluating the general well-being of children and their communities, while also playing a vital role in tracking progress toward various goals of health and broader societal equity.[2] In addition, they help to alleviate concerns over abnormal development, foster healthy advancement, and identify underlying illnesses.[3]

In April 2006, the World Health Organization (WHO) published updated



**How to cite this article:** Bataineh L, Al-Qerem W, Jarab A, Alasmari F, Eberhard J. Significant differences in the length and weight measurements of Jordanian infants compared to the World Health Organization 2006 growth standards. J Fam Community Med 2024;31:124-32.

growth standards for infants and children based on the Multicenter Growth Reference Study (MGRS) conducted in Brazil, Ghana, India, Norway, Oman, and the USA.[4] The MGRS, conducted from 1997 to 2003, employed a meticulous approach to aggregate data, ensuring an accurate representation of growth patterns across diverse populations without compromising the validity of the reference standards. To achieve this, a medium effect size of 0.5 standard deviations (SDs) served as a cutoff point during data pooling. This particular threshold was carefully chosen to guarantee that the data captured the diversity of populations while minimizing the impact of differences that might influence the accuracy of reference data in clinical or public health contexts.[4] These standards aim to provide internationally representative guidelines for optimal growth in healthy individuals.[5] The WHO states that breastfed infants and economically advantaged children display comparable patterns of unrestricted growth, allowing for a single set of growth curves to represent typical human physiology.[6] These curves, known as growth standards, serve as benchmarks applicable to all nations, regardless of genetic or cultural background.[7] However, it is important to emphasize that variations in children's body size and shape across populations are attributable to discrepancies in genetic pools, environments, and the interplay between both.[8]

Although the WHO growth standards are designed to reflect optimal conditions, disparities in economics, society, and the environment in various regions can impede children's growth and development.[9] As a result, there is an increasing focus on validating these standards in different geographic locations, and numerous studies have been conducted to validate their accuracy, reliability, and applicability to local populations.[10] It is worth noting that 25 out of 145 countries have developed their own growth standards to be specific to the population being assessed, considering factors such as genetics, ethnicity, and environmental conditions that can influence growth patterns.[10] In nations with a diverse ethnic populace, there may be a range of growth requirements.[11] Specifically, in some countries, such as Belgium, Netherlands, Norway, and Denmark, infants were found to be taller than the WHO standards, whereas in other countries, such as China and Iran, infants were found to be shorter than the WHO standards.[10]

Despite the significant recent improvements in healthcare services, there is a scarcity of research on the growth pattern of Jordanian children, and there is an ongoing debate regarding the applicability of international standards owing to potential variations in economic, social, and ethnic contexts of different populations.[12] This study seeks to gain insights into the suitability and precision of applying WHO growth standards to children in Jordan, focusing on comparing reference equations for key parameters such as weight-for-age (WFA), length-for-age (LFA), and weight-for-length (WFL).

## Materials and Methods

The present study is based on all data available from a National E-health Program between April 2016 and June 2023. This data includes a diverse sample from Northern, Central, and Southern Jordan to represent Jordanian paediatrics. Employing a cross-sectional design, data on paediatrics aged 0–24 months were collected from 115 maternal and child health centers, using the Hakeem Program. This program, integral to Jordan's healthcare system, uses an electronic health record system to enhance efficiency and quality. Nurses trained in using the Hakeem platform ensure compliance with WHO measurement standards. Ethical approval was obtained from the Institutional Review Board (IRB) vide Letter No.IRB-02/581/2021-2/2022 dated 13/06/2022, with a waiver of informed consent since there was no direct relation with human subjects in this study.

A comprehensive examination of the provided anthropometric data, including weight and recumbent length, was meticulously conducted to ensure adherence to the recognized measurement techniques set by the WHO.[13] Simultaneously, vital demographic details, such as gender, date of birth, and visit date, were recorded, enabling precise determination of each child's age at the time of measurement. Furthermore, researchers extensively assessed the health and medication history of each infant to identify factors influencing growth and development.

For consistency and comparability, this study followed WHO standards and focused on healthy full-term infants. Data accuracy and reliability were ensured through refinement and cleaning techniques, including the removal of duplicate entries, unavailable data, and biologically implausible values. To improve data quality, outliers were identified and excluded based on NCHS/WHO guidelines. Exclusion ranges were applied for LFA (<- 5 and >+ 3), WFA (<- 5 and >+ 5), and WFL (<-4 and >+5) $z$-score values.[14] Figure 1 indicates the sample recruitment flowchart.

All statistical analyses were performed using Statistical Package for the Social Sciences Software (IBM SPSS Statistics for Windows, version 26, IBM Corporation, Armonk, NY, USA: IBM Corp[15] and R studio with anthro package.[16] To ensure uniformity, all infant measurements were converted into standard units: length was converted into centimeters, and weight was converted into kilograms. Furthermore, the measurements were categorized by sex to enable

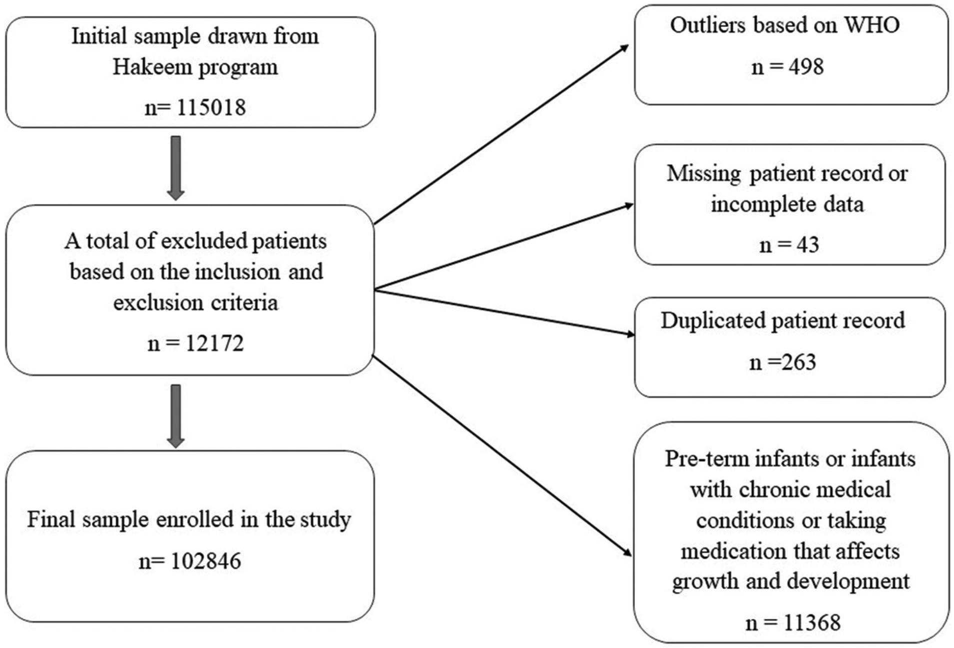


**Figure 1:** Sample recruitment and exclusion flowchart. WHO = World Health Organization

sex-specific analysis. Q-Q plots were examined and Kolmogorov–Smirnov test was performed to analyze the distribution of the data, and the result indicated that the data were not normally distributed, which could be due to the lack of symmetry in the number of infants in each age group. Thus, Mann–Whitney *U* tests were performed to determine whether there were any significant differences between the measurements of boys and girls in terms of age, length, and weight. Sex-specific median with a 95% Confidence level (CL) was measured and a significance level of 0.05 (i.e., a $P < 0.05$) was chosen to determine statistical significance.

For each infant, mean *z*-scores with 95% Confidence Interval (CI) and SD for length, weight, and weight for length were calculated relative to the WHO 2006 Growth Standards.[7] To evaluate the impact of dissimilarities between these variables and the 2006 WHO standards, Cohen's criteria were used to determine the effect size and its practical significance. Cohen's criteria provide a standardized method whereby an effect size of 0.2 SD is categorized as small, 0.5 SD as moderate, and 0.8 SD or more as large.[17] If the measurements of populations were shown to have variances greater than ± 0.5 SDs, according to Cohen's criteria, those nations were considered as deviating from the WHO 2006 Growth Standards.[18] The rationale behind selecting ± 0.5 SDs as the threshold stems from a desire to balance statistical significance with clinical relevance, ensure consistency with previous research, align with established effect size criteria, and maintain global health relevance. This approach aims to provide a meaningful and interpretable standard for identifying deviations from WHO standards in a manner that is both statistically robust and clinically significant.[17,19] This is in accordance with previous research[20] and WHO recommendations.[4]

## Results

The final analysis included 102,018 infants (51,587 boys and 51,259 girls). The age at which measurements were captured was converted into days and organized into age intervals based on the WHO standards.[7] Table 1 presents an overview of these age intervals, as well as the corresponding number of participants for each gender.

A thorough analysis of the data indicated statistically significant disparities in length and weight between boys and girls, with $P < 0.0001$ for both parameters. Specifically, boys had taller stature and higher weight compared to their girl counterparts. The median length for boys was 61 cm, whereas girls exhibited a median of 59.99 cm. Similarly, the median weight for boys was recorded as 6.40 kg, while girls had a median weight of 6.00 kg [Table 2].

A comparative analysis of LFA, WFA, and WFL measurements of Jordanian infants against the 2006 WHO growth standards revealed that the mean birth length of both boys and girls fell below the WHO standards, with mean *z*-scores of −0.52 and −0.35, respectively. These discrepancies persisted across all age categories. Notably, boys exhibited the most significant variations at 1–2 months and 22–24 months, where the mean *z*-scores were −0.91 and −1.21, respectively [Table 3].

For girls, the deviation from the WHO standards was pronounced until they reached 9–10 and 10–11 months, at which point the mean length became comparable to the WHO growth standards with mean *z*-scores of −0.07 and −0.08, respectively. However, beyond these ages, girls continued to show deviations and remained shorter than the WHO standards [Table 4]. Overall, the LFA measurements for both boys and girls indicated by mean *z*-scores of −0.56 and −0.38, respectively, were statistically shorter than the WHO standards. A distinct WFA pattern between boys and girls at birth was observed. Boys exhibited birth weights that were in line with the 2006 WHO standards, showing no significant differences during the 1st month of life (mean *z*-score = −0.07). However, from the 2nd to the 6th month, boys displayed slightly lower weights compared to the WHO standards. By the 9th month, the mean *z*-score indicated that boys were slightly heavier than the standards (0.41) [Table 3]. Conversely, baby girls showed a weight pattern that exceeded the WHO standards during the 1st month of life, with a mean *z*-score of 0.51 at 0–2 weeks and 0.21 at 2–4 weeks. However, by the 2nd month, their weight became comparable to the WHO standards (mean *z*-score = 0.05). Minor deviations from the standards were observed during the 3rd and 4th months, with a mean *z*-score of −0.21, but no significant deviations were observed after that time, except for a slight increase in weight between 9 and 10 months and a slight decrease between 22 and 24 months, with mean *z*-scores of 0.28 and −0.26, respectively [Table 4]. The WFA of both boys and girls in this study was generally comparable to the 2006 WHO standards, with no significant differences (mean *z* score = −0.05 and 0.04, respectively).

**Table 1: Distribution of Jordanian children aged 0-24 months by age and sex, Jordan**

| Age (days) | Group | Boys *N* (%) | Girls *N* (%) | Total *N* (%) |
|---|---|---|---|---|
| 0–14 | Birth | 6509 (12.6) | 4240 (8.2) | 10,749 (10.5) |
| 14–28 | 2 weeks | 5688 (11.0) | 5231 (10.2) | 10,919 (10.7) |
| 28–42 | 4 weeks | 3337 (6.5) | 3565 (6.7) | 6902 (6.7) |
| 42–60 | 6 weeks | 2114 (4.1) | 2513 (4.9) | 4627 (4.5) |
| 60–90 | 2 months | 6200 (12.0) | 6718 (13.1) | 12,918 (12.6) |
| 90–120 | 3 months | 4145 (8.0) | 4528 (8.9) | 8673 (8.5) |
| 120–150 | 4 months | 3306 (6.4) | 3844 (7.5) | 7150 (6.9) |
| 150–180 | 5 months | 1697 (3.3) | 1893 (3.7) | 3590 (3.4) |
| 180–210 | 6 months | 1123 (2.2) | 1174 (2.3) | 2297 (2.2) |
| 210–240 | 7 months | 599 (1.2) | 614 (1.2) | 1213 (1.2) |
| 240–270 | 8 months | 468 (0.9) | 500 (1.0) | 968 (0.9) |
| 270–300 | 9 months | 3548 (6.9) | 3908 (7.7) | 7456 (7.3) |
| 300–330 | 10 months | 2001 (3.9) | 2202 (4.4) | 4203 (4.1) |
| 330–360 | 11 months | 572 (1.1) | 629 (1.2) | 1201 (1.2) |
| 360–420 | 12 months | 3092 (6.0) | 3120 (6.1) | 6212 (6.0) |
| 420–480 | 14 months | 492 (1.0) | 512 (1.0) | 1004 (1.0) |
| 480–540 | 16 months | 414 (0.8) | 437 (0.9) | 851 (0.8) |
| 540–600 | 18 months | 4528 (8.8) | 4054 (8.0) | 8582 (8.2) |
| 600–660 | 20 months | 1159 (2.2) | 1070 (2.1) | 2229 (2.2) |
| 660–730 | 24 months | 595 (1.2) | 507 (1.0) | 1102 (1.1) |
| Total sample | Birth-24 months | 51,587 (50.1) | 51,259 (49.9) | 102,846 (100) |

The WFL measurements for boys displayed a substantial deviation from WHO standards, with a mean *z*-score of 0.51 across all age intervals. The most significant deviation occurred during the 2nd month of the baby's life, with a mean *z*-score of 0.9 [Table 3]. Similarly, girls displayed a notable deviation from the WHO standards, with a mean *z*-score of 0.47 for all age categories. The most deviation for girls was observed during the first 2 months of life [Table 4]. These findings indicate that both boys and girls exhibited higher WFL measurements compared to the WHO standards. For greater clarity, Figures 2a and b visually illustrate the growth patterns in LFA for boys and girls, respectively, overlaying the data onto the 3rd, 15th, 50th, 85th, and 97th centiles of the 2006 WHO growth standards. Furthermore, Figures 2c and d depict the overlay of WFA for boys and girls, respectively, providing a comprehensive visual understanding of both length and weight development across various centiles.

## Discussion

This comprehensive population-based investigation revealed notable sex-specific variations in the length and weight measurements of Jordanian infants during the initial 24 months of life. The analysis showed that boys manifest significantly higher height and weight measurements in comparison to girls, with a statistically significant $P = 0.001$. These findings are consistent with prior research indicating distinct sex-specific growth patterns observed in diverse populations.[21] The robustness of the study, owing to its large sample size, representative of the composition of the Jordanian population, augments the reliability of the obtained results. The observed sex-specific discrepancies in growth have significant implications for healthcare providers and policymakers, particularly concerning nutrition and growth monitoring practices.

**Table 2: Sex-specific descriptive statistics for Jordanian infants: Comparison of length and weight**

| | Boys (*n*=51,587) | | Girls (*n*=51,259) | | *P*-value |
|---|---|---|---|---|---|
| | Median | 95.0% CI for median | Median | 95.0% CI for median | |
| Length (cm) | 61.00064 | 61.00064–61.99886 | 59.99988 | 59.99988–61.00064 | 0.0001 |
| Weight (kg) | 6.405940 | 6.405940–6.505820 | 6.006420 | 6.006420–6.106300 | 0.0001 |

CI=Confidence interval

**Table 3: Boy's means and 95% confidence intervals for *Z* scores of lengths, weight, and weight for length, with reference to the World Health Organization growth standards**

| Age group (days) | Number of boys | Mean length (95% CI) | SD | Mean weight (95% CI) | SD | Length for age | | Weight for age | | Weight for length | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean (95% CI) | SD | Mean (95% CI) | SD | Mean (95% CI) | SD |
| 0–14 | 6509 | 50.31 (50.25–50.37) | 2.30 | 3.53 (3.52–3.55) | 0.38 | −0.52 (−0.55–−0.49) | 1.24 | −0.07 (−0.10–−0.05) | 0.96 | 0.29 (0.25–0.33) | 1.61 |
| 14–28 | 5688 | 51.79 (51.72–51.85) | 2.42 | 3.98 (3.97–4.00) | 0.44 | −0.79 (−0.83–0.76) | 1.30 | −0.15 (−0.17–−0.12) | 0.98 | 0.62 (0.58–0.67) | 1.61 |
| 28–42 | 3337 | 53.64 (53.54–53.73) | 2.35 | 4.56 (4.54–4.59) | 0.55 | −0.92 (−0.96–−0.87) | 1.36 | −0.25 (−0.29–−0.22) | 1.06 | 0.87 (0.82–0.93) | 1.67 |
| 42–60 | 2114 | 55.26 (55.14–55.38) | 2.56 | 5.04 (5.01–5.07) | 0.57 | −0.91 (−0.98–−0.85) | 1.43 | −0.27 (−0.32–−0.22) | 1.13 | 0.90 (0.83–0.97) | 1.66 |
| 60–90 | 6200 | 58.07 (57.99–58.14) | 2.76 | 5.66 (5.64–5.67) | 0.64 | −0.64 (−0.68–−0.61) | 1.41 | −0.29 (−0.31–−0.26) | 1.05 | 0.48 (0.44–0.52) | 1.53 |
| 90–120 | 4145 | 61.25 (61.16–61.34) | 2.85 | 6.46 (6.43–6.48) | 0.74 | −0.58 (−0.62–−0.54) | 1.42 | −0.29 (−0.32–−0.25) | 1.10 | 0.28 (0.23–0.32) | 1.47 |
| 120–150 | 3306 | 63.85 (63.75–63.95) | 2.91 | 7.13 (7.10–7.16) | 0.81 | −0.46 (−0.50–−0.41) | 1.40 | −0.19 (−0.23–−0.15) | 1.16 | 0.24 (0.19–0.28) | 1.42 |
| 150–180 | 1697 | 65.42 (65.27–65.58) | 3.12 | 7.51 (7.46–7.56) | 0.84 | −0.55 (−0.62–−0.48) | 1.51 | −0.27 (−0.33–−0.21) | 1.23 | 0.21 (0.14–0.27) | 1.43 |
| 180–210 | 1123 | 67.24 (67.05–67.43) | 3.11 | 8.10 (8.03–8.16) | 0.91 | −0.42 (−0.51–−0.33) | 1.52 | −0.02 (−0.09–0.05) | 1.24 | 0.42 (0.34–0.51) | 1.44 |
| 210–240 | 599 | 68.61 (68.33–68.89) | 3.33 | 8.36 (8.28–8.45) | 0.99 | −0.50 (−0.62–−0.37) | 1.58 | −0.12 (−0.22–−0.02) | 1.21 | 0.34 (0.23–0.45) | 1.37 |
| 240–270 | 468 | 70.11 (69.81–70.41) | 3.40 | 8.87 (8.76–8.97) | 1.02 | −0.44 (−0.57–−0.30) | 1.49 | 0.09 (−0.02–0.2) | 1.21 | 0.53 (0.40–0.66) | 1.43 |
| 270–300 | 3548 | 72.22 (72.12–72.32) | 3.12 | 9.46 (9.42–9.50) | 0.96 | −0.09 (−0.14–−0.05) | 1.36 | 0.41 (0.37–0.44) | 1.13 | 0.66 (0.62–0.71) | 1.33 |
| 300–330 | 2001 | 73.18 (73.04–73.32) | 3.20 | 9.56 (9.51–9.61) | 0.95 | −0.19 (−0.26–−0.13) | 1.42 | 0.26 (0.21–0.31) | 1.12 | 0.52 (0.47–0.58) | 1.32 |
| 330–360 | 572 | 73.38 (73.09–73.66) | 3.73 | 9.60 (9.50–9.69) | 1.01 | −0.64 (−0.76–−0.51) | 1.48 | 0.06 (−0.03–0.25) | 1.11 | 0.52 (0.41–0.63) | 1.36 |
| 360–420 | 3092 | 75.69 (75.56–75.81) | 3.36 | 10.12 (10.08–10.17) | 0.96 | −0.28 (−0.34–−0.23) | 1.45 | 0.27 (0.23–0.31) | 1.07 | 0.56 (0.51–0.60) | 1.29 |
| 420–480 | 492 | 77.55 (77.20–77.90) | 3.79 | 10.41 (10.29–10.52) | 1.01 | −0.48 (−0.62–−0.35) | 1.56 | 0.08 (−0.02–0.19) | 1.18 | 0.42 (0.30–0.55) | 1.39 |
| 480–540 | 414 | 79.78 (79.41–80.15) | 4.08 | 10.91 (10.78–11.03) | 1.10 | −0.49 (−0.63–−0.35) | 1.44 | 0.12 (0.01–0.22) | 1.08 | 0.47 (0.35–0.60) | 1.28 |
| 540–600 | 4528 | 81.48 (81.38–81.59) | 3.74 | 11.46 (11.42–11.50) | 0.98 | −0.49 (−0.53–−0.46) | 1.30 | 0.27 (0.24–0.30) | 1.04 | 0.68 (0.64–0.71) | 1.24 |
| 600–660 | 1159 | 82.18 (81.97–82.39) | 4.00 | 11.59 (11.51–11.67) | 1.00 | −0.88 (−0.95–−0.80) | 1.30 | 0.05 (−0.01–0.11) | 1.05 | 0.64 (0.57–0.72) | 1.28 |
| 660–730 | 595 | 83.11 (82.83–83.40) | 4.03 | 11.84 (11.72–11.95) | 1.07 | −1.21 (−1.30–−1.11) | 1.18 | −0.11 (−0.19–−0.02) | 1.08 | 0.67 (0.56–0.78) | 1.35 |
| Total sample | 51,587 | 62.70 (62.61–62.79) | 10.45 | 6.62 (6.60–6.64) | 2.41 | −0.56 (−0.58–−0.55) | 1.39 | −0.05 (−0.06–−0.04) | 1.10 | 0.51 (0.50–0.53) | 1.49 |

CI=Confidence interval, SD=Standard deviation

**Table 4: Girl's means and 95% confidence intervals for *Z* scores of lengths, weight, and weight for length, with reference to the World Health Organization growth standards**

| Age group (days) | Number of girls | Mean length (95% CI) | SD | Mean weight (95% CI) | SD | Length for age | | Weight for age | | Weight for length | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean (95% CI) | SD | Mean (95% CI) | SD | Mean (95% CI) | SD |
| 0–14 | 4240 | 50.14 (50.07–50.21) | 2.30 | 3.71 (3.70–3.72) | 0.38 | −0.35 (−0.39–−0.32) | 1.22 | 0.51 (0.49–0.53) | 0.72 | 0.92 (0.89–0.96) | 1.29 |
| 14–28 | 5231 | 51.29 (51.22–51.35) | 2.42 | 3.95 (3.94–3.96) | 0.44 | −0.58 (−0.62–−0.55) | 1.24 | 0.21 (0.19–0.23) | 0.78 | 0.83 (0.80–0.87) | 1.42 |
| 28–42 | 3565 | 53.47 (53.40–53.55) | 2.35 | 4.44 (4.43–4.46) | 0.55 | −0.47 (−0.51–−0.43) | 1.16 | 0.05 (0.02–0.08) | 0.85 | 0.67 (0.62–0.72) | 1.45 |
| 42–60 | 2513 | 54.46 (54.36–54.56) | 2.56 | 4.78 (4.75–4.80) | 0.57 | −0.66 (−0.71–−0.61) | 1.27 | −0.04 (−0.08–−0.01) | 0.94 | 0.83 (0.77–0.89) | 1.51 |
| 60–90 | 6718 | 56.81 (56.74–56.88) | 2.76 | 5.25 (5.23–5.26) | 0.64 | −0.54 (−0.58–−0.51) | 1.32 | −0.21 (−0.23–−0.18) | 0.93 | 0.46 (0.42–0.49) | 1.45 |
| 90–120 | 4528 | 59.88 (59.79–59.96) | 2.85 | 5.97 (5.95–5.99) | 0.74 | −0.42 (−0.46–−0.38) | 1.32 | −0.21 (−0.24–−0.19) | 0.98 | 0.25 (0.21–0.29) | 1.39 |
| 120–150 | 3844 | 62.21 (62.12–62.31) | 2.91 | 6.56 (6.53–6.58) | 0.81 | −0.33 (−0.38–−0.29) | 1.31 | −0.15 (−0.18–−0.12) | 1.00 | 0.23 (0.19–0.27) | 1.30 |
| 150–180 | 1893 | 63.89 (63.75–64.03) | 3.12 | 6.98 (6.94–7.01) | 0.84 | −0.36 (−0.42–−0.29) | 1.38 | −0.15 (−0.19–−0.10) | 0.99 | 0.24 (0.19–0.30) | 1.28 |
| 180–210 | 1174 | 65.36 (65.18–65.54) | 3.11 | 7.40 (7.35–7.46) | 0.91 | −0.38 (−0.46–−0.30) | 1.36 | −0.07 (−0.13–−0.01) | 1.03 | 0.35 (0.27–0.42) | 1.26 |
| 210–240 | 614 | 66.90 (66.63–67.16) | 3.33 | 7.77 (7.69–7.85) | 0.99 | −0.40 (−0.51–−0.28) | 1.43 | −0.05 (−0.14–0.03) | 1.08 | 0.36 (0.25–0.46) | 1.32 |
| 240–270 | 500 | 68.29 (67.99–68.59) | 3.40 | 8.04 (7.95–8.13) | 1.02 | −0.38 (−0.51–−0.25) | 1.44 | −0.07 (−0.16–0.03) | 1.07 | 0.30 (0.19–0.41) | 1.23 |
| 270–300 | 3908 | 70.43 (70.33–70.53) | 3.12 | 8.67 (8.64–8.70) | 0.96 | −0.07 (−0.11–−0.03) | 1.28 | 0.28 (0.25–0.31) | 0.93 | 0.51 (0.47–0.54) | 1.11 |
| 300–330 | 2202 | 71.63 (71.50–71.76) | 3.20 | 8.79 (8.75–8.83) | 0.95 | −0.08 (−0.13–−0.03) | 1.29 | 0.18 (0.14–0.21) | 0.92 | 0.35 (0.30–0.39) | 1.10 |
| 330–360 | 629 | 72.58 (72.29–72.87) | 3.73 | 8.91 (8.83–8.99) | 1.01 | −0.21 (−0.33–−0.10) | 1.47 | 0.06 (−0.02–0.13) | 0.95 | 0.27 (0.18–0.35) | 1.14 |
| 360–420 | 3120 | 74.25 (74.14–74.37) | 3.36 | 9.29 (9.26–9.32) | 0.96 | −0.16 (−0.20–−0.11) | 1.28 | 0.15 (0.12–0.18) | 0.87 | 0.31 (0.28–0.35) | 1.03 |
| 420–480 | 512 | 76.39 (76.06–76.72) | 3.79 | 9.62 (9.53–9.71) | 1.01 | −0.25 (−0.37–−0.13) | 1.37 | 0.04 (−0.04–0.11) | 0.89 | 0.20 (0.11–0.30) | 1.08 |
| 480–540 | 437 | 78.63 (78.25–97.02) | 4.08 | 9.94 (9.84–10.05) | 1.10 | −0.31 (−0.45–−0.18) | 1.42 | −0.10 (−0.19–−0.02) | 0.93 | 0.04 (−0.06–0.15) | 1.11 |
| 540–600 | 4054 | 80.66 (80.54–80.77) | 3.74 | 10.53 (10.50–10.56) | 0.98 | −0.22 (−0.26–−0.19) | 1.27 | 0.09 (0.06–0.11) | 0.79 | 0.24 (0.21–0.27) | 0.91 |
| 600–660 | 1070 | 81.95 (81.71–82.19) | 4.00 | 10.71 (10.65–10.77) | 1.00 | −0.41 (−0.49–−0.34) | 1.31 | −0.08 (−0.13–−0.03) | 0.79 | 0.13 (0.07–0.19) | 0.95 |
| 660–730 | 507 | 83.61 (83.26–83.97) | 4.03 | 10.94 (10.85–11.03) | 1.07 | −0.55 (−0.66–−0.44) | 1.28 | −0.26 (−0.34–−0.19) | 0.83 | −0.03 (−0.12–0.06) | 1.03 |
| Total sample | 51,259 | 62.70 (62.61–62.79) | 10.45 | 6.62 (6.60–6.64) | 2.41 | −0.38 (−0.39–−0.36) | 1.30 | 0.04 (0.03–0.05) | 0.92 | 0.47 (0.46–0.48) | 1.31 |

CI=Confidence interval, SD=Standard deviation

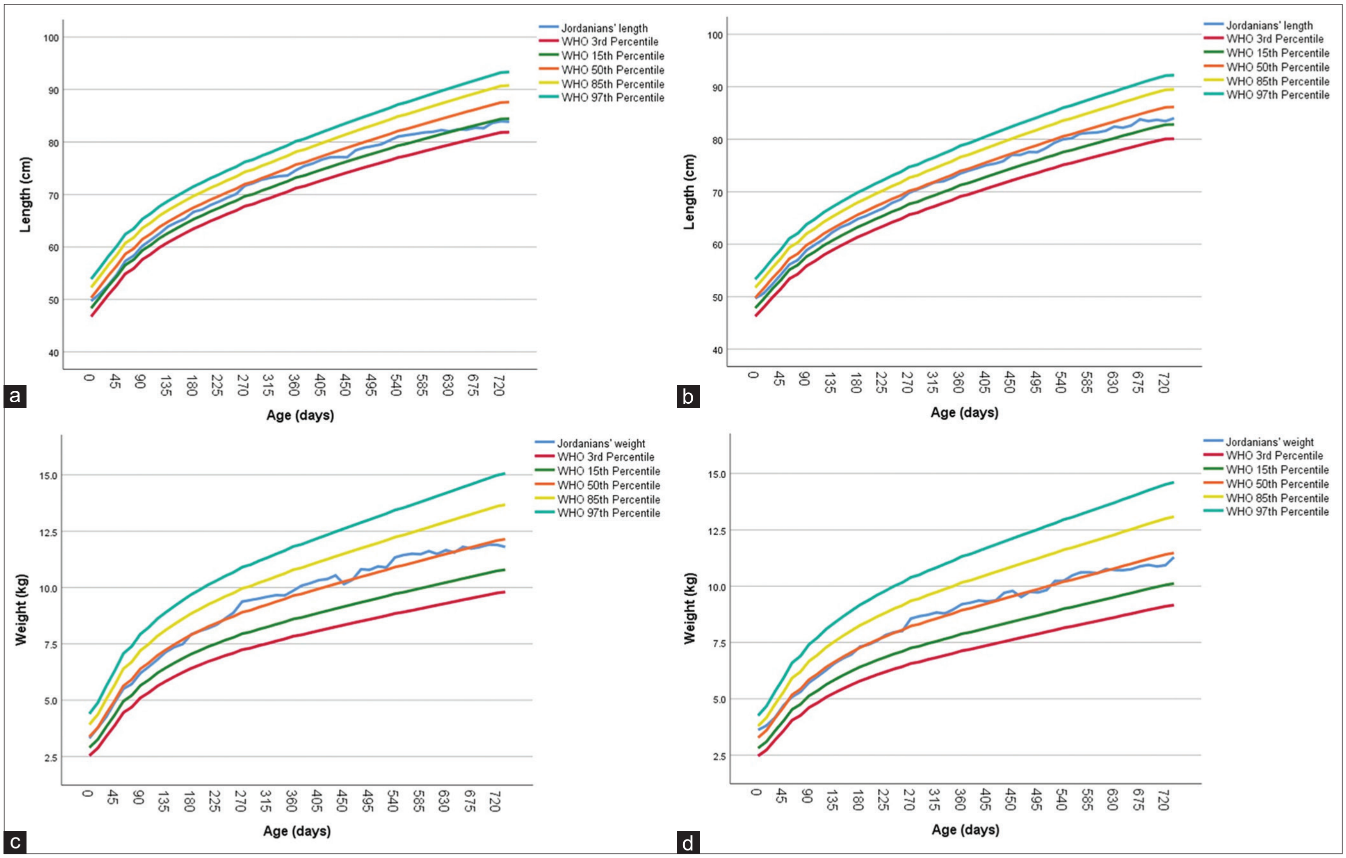


**Figure 2:** (a) Growth patterns of Jordanian boys: Length-for-age overlay on 2006 World Health Organization (WHO) curves. (b) Growth patterns of Jordanian girls: Length-for-age overlay on 2006 WHO curves. (c) Growth patterns of Jordanian boys: Weight-for-age overlay on 2006 WHO curves. (d) Growth patterns of Jordanian girls: Weight-for-age overlay on 2006 WHO curves. WHO = World Health Organization

Tailored interventions are imperative to promote healthy growth in both male and female infants in the Jordanian population. Therefore, the study underscores the importance of considering sex-specific variations when devising and implementing growth monitoring programs. This involves the utilization of sex-specific growth charts and the implementation of personalized interventions to facilitate optimal growth in infants of both sexes.

The WHO Child Growth Standards were developed to be universally applicable, depicting normal growth under optimal environmental conditions.[5] The underlying assumption is that all children have the potential to achieve full and optimal growth with appropriate health recommendations and care practices, regardless of their ethnicity, socioeconomic status, and feeding practices.[4] The WHO MGRS adopted a meticulous approach to pool data, ensuring the accurate representation of growth patterns across diverse populations without compromising the validity of the reference standards.[1] To achieve this, a medium effect size of 0.5 SDs was used as a cutoff point during data pooling. This threshold was selected to ensure that the data captured the diversity of populations, but minimized the impact of differences that might affect the accuracy of reference data in clinical or public health contexts.[22] Differences below this 0.5 SD threshold were considered to have minimal practical significance in clinical or public health settings.[17] However, many recent studies indicate that the growth patterns observed in economically privileged children do not align with the means of the MGRS.[10] Studies conducted in Indonesia, Japan, China, and Canada have raised concerns about the applicability of WHO standards to different populations.[20,23-25] In Indonesia, healthy infants exhibited lower $z$-scores for WFA and LFA, particularly in the initial 6 months, suggesting a potential overestimation of chronic undernutrition in East Asian populations.[25] Conversely, a Japanese study found significant changes in rates of short stature, underweight, and overweight when implementing the WHO standards to Japanese children.[20] In China, a recommendation emerged for a tailored growth chart, as Chinese infants consistently demonstrated lower mean weight and length compared to WHO standards across all age groups.[24] In addition, a Canadian study revealed lower mean birth weight of Canadian infants compared to WHO standards,[23] and research in Libya found that children had lower mean weight and height compared to the reference populations in WHO growth standards.[26] These diverse findings underscore the importance of considering comparable economic, social, and ethnic backgrounds when evaluating growth standards in different populations.

In the present study, significant differences were observed in the age- and sex-specific length and weight measurements of Jordanian infants compared to the WHO 2006 growth standards. Specifically, the LFA measurements consistently indicated that Jordanian infants exhibited lower values, as evidenced by consistently low mean SD scores in all age categories. Thus, the length of Jordanian infants fell well below the international growth standards established by the WHO. Regarding weight measurements, minimal variations were found between Jordanian infants and the WHO standards, with distinct patterns emerging at birth for boys and girls. Newborn boys exhibited weight measurements comparable to the WHO standards, while newborn girls were heavier than the universal standards at birth. However, as the study progressed with age, the mean weight SD scores for both boys and girls approached a more comparable level with the WHO standards across all age categories. These findings suggest that, overall, Jordanian infants had weight measurements comparable to the WHO standards without deviating significantly. By using WHO task force guidelines as a reference,[4] the differences between the studied population in this study and the WHO standards ranged from small to large, underscoring the importance of understanding the variations in growth patterns in different populations.

The study found that Jordanian infants exhibit lower LFA, distinctive WFA patterns, and higher WFL measurements in their first 24 months compared to the WHO standards. Relying on universal standards may lead to misinterpretation, causing both overdiagnosis and underdiagnosis of growth-related concerns. This can result in disparities in access to healthcare, unnecessary interventions, referrals, and parental distress. These factors can also carry cultural and psychological implications. Interestingly, these findings differ from a previous national study conducted in 1995, which examined growth patterns in Jordanian children and indicated that the growth potential of Jordanian children was like that of American children at specific ages when using the NCHS reference population as a reference point.[27] However, the current study underscores the necessity for developing localized growth standards to assess the growth of children at the clinic level.

The observed deviations in Jordanian infants from the WHO standards could be partially ascribed to the country's breastfeeding patterns, as the WHO standards are based on breastfed infants.[4] Notably, the most substantial disparities between Jordanian infants and the standards were evident in length measurements, which might be influenced by epigenetic constraints on growth.[28] However, the specific reasons underlying these differences in length remain unclear. Notably, existing research suggests that these differences are likely unrelated to feeding practices, as breastfed infants generally exhibit slower growth patterns compared to formula-fed infants after 2–3 months of age, with weight as the primary distinguishing factor rather than length.[29] Bearing these findings in mind, there is merit in considering the development of localized growth standards based on breastfed infants for certain populations. Such standards are crucial to the accurate assessment and monitoring of the growth and development of infants in specific regions, accounting for any unique factors, including breastfeeding patterns and potential epigenetic influences on growth. Although the differences in WFA between Jordanian infants and the WHO standards are minor, the deviations in LFA were more substantial, particularly at 22–24 months.

Nevertheless, the present study offers several noteworthy strengths that greatly enhance the understanding of infant growth patterns. One major strength is the careful adherence to WHO criteria in selecting a well-nourished population, representing the entire country through well-defined sampling from different regions. This ensured a representative sample that minimized selection bias. In addition, the study utilized a large population-based sample, one of the largest in Jordan, which consequently enhanced result reliability and facilitated valuable subgroup analyses. Furthermore, the detailed health information obtained on the infants enabled the exclusion of unhealthy subjects or those on medications that could affect growth. Consequently, the sample included only healthy infants with no medical conditions or treatments, and precisely match the Jordanian population to the WHO standard. This enhanced the validity and reliability and provided an accurate representation of unique growth patterns and specific health needs in Jordanian infants.

The study acknowledges limitations, such as the lack of assessment for measurement consistency by different nurses, potentially affecting accuracy and reliability. In addition, the absence of data on the smoking habits of Jordanian mothers hindered the determination of the exact influence on infant growth of active maternal smoking during pregnancy. However, previous research has shown significant links between maternal smoking during pregnancy and adverse child growth outcomes, including a higher likelihood of low birth weight and impaired linear growth.[30,31] Another limitation of the study is the absence of data on breastfeeding habits in the dataset on the possible impact on the observed growth patterns. A prior Jordanian study revealed a low breastfeeding rate, indicating that only 24% of infants were breastfed at 2–3 months of age.[32] Comparing the growth patterns of breastfed infants with formula-fed infants is a common practice in such studies as previous studies have indicated that there are minimal differences in growth, in terms of weight and length, between breastfed and formula-fed infants during the first 6–8 weeks of life. However, starting from around 2 months of age until the end of the 1st year of life, formula-fed infants tend to gain weight and length more rapidly than breastfed infants.[33]

## Conclusion

Unlike the WHO study group's findings that suggest similarity in children's lengths across populations, our study highlights distinctive patterns in Jordanian infants, showing generally shorter stature compared to WHO growth standards. This difference possibly stems from epigenetic factors and not inadequate nutrition. Misclassifying children based on inappropriate standards may cause anxiety or hinder the recognition of overweight trends. This study should inspire future research to better understand the growth patterns in diverse Middle Eastern populations, and contribute to a comprehensive understanding of regional disparities in child growth and development. In addition, it should encourage further research in developing population-specific growth charts.

### Financial support and sponsorship
Nil.

### Conflicts of interest
There are no conflicts of interest.

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