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Percentile Rankings and Normalization of Performance for Youth International Weightlifting Federation World Championships Competitors

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ABSTRACT

The present study provided percentile rankings and comparisons based on sex and weight class for absolute and normalized Olympic Weightlifting (OW) performance for youth International Weightlifting Federation (IWF) World Championships competitors. Data from the IWF Youth World Championships from 2019, 2021, 2022, and 2023 were used. Allometric scaling normalized OW performance to body weight, and Sinclair scores were calculated based on IWF standards. Percentile rankings and sex and weight class differences were analyzed. In general, boys were stronger than girls for absolute and allometrically scaled OW performance, and Sinclair scores. Within boys and girls, absolute OW performance increased with weight class, while the middle weight classes tended to have superior performance than the lightest and heaviest weight classes when allometrically scaled. For the boys, Sinclair scores were greater for the middle weight classes compared to the lightest and heaviest weight classes. For the girls, there were no differences across weight class for Sinclair scores. The present study provides sex- and weight class-specific percentile rankings for absolute and normalized performance for youth OW competitors. These data may be valuable for assessing youth OW competitors and when considering appropriate weight classes for these competitors.

Keywords: youth; resistance; weight; sex; performance.

INTRODUCTION

Olympic Weightlifting (OW) is a popular international sport involving two competition lifts: the snatch and the clean & jerk. Although the OW exercises are commonly used in strength and conditioning programs (25), OW is itself a sport with national and international competitions, including the Olympic Games. In strength and conditioning programs, it is common to use various derivatives of the snatch and clean & jerk exercises, such as snatch and clean pulls and hang snatch and clean. However, just because a weightlifting movement or derivative is used in a program does not indicate that an individual is competing within OW. Within OW, the various age categories include youth: 13-17-years-old, junior: 15-20-years-old, senior: ≥ 15-years-old, and masters: ≥ 35-years-old. Olympic Weightlifting has grown in popularity among youth competitors (10), increasing by almost 100 competitors in the World Championship competitions over the last 5-years. with national and international competitions for boys and girls desiring to compete in the sport of

Weightlifting. Similar to senior level OW competitors, boys and girls are separated into 10 body weight classifications to allow individuals to compete against others with similar body weight within their sex. Within each sex and weight class, competitors are awarded 1st, 2nd, or 3rd place recognition for the highest weight lifted for the snatch, clean & jerk, and combined total of both lifts. Beyond the absolute weight lifted, OW competitions also use the Sinclair coefficient (11), a mathematical formula that accounts for differences in body weight, to determine the best overall lifter across all body weight classifications, providing competitors the "best lifter" award. Although the growth of the sport of OW has led to increases in amateur competitions at the senior and youth level, the International Weightlifting Federation (IWF), the international governing body of the sport of OW, hosts the World Championships to allow elite OW competitors to compete against other athletes of the same caliber. Thus, amateur OW competitors tend to look at the performance of elite competitors to gauge their current OW performance, particularly those who aspire to compete at the highest level.

One valuable method that can be used for OW coaches and competitors to assess performance is by comparing current performance to normative reference values (i.e., percentile rankings) based on previous IWF competitive results. Although previous studies and texts have provided OW percentile rankings for athletic populations (4,6,7), predominantly at the adult level, there are no percentile rankings for youth OW competitors in the sport of Weightlifting. One previous study has published percentile rankings based on sex and weight class among IWF World Championships senior competitors (4), which may prove valuable for senior level coaches and athletes, but these rankings are inappropriate for youth competitors. Thus, it seems pertinent to provide these metrics for youth OW competitors to provide an accurate standard by which performance may be compared. Furthermore, since the IWF also considers the influence of body weight on performance through the Sinclair coefficient (11,24), it is important to understand how body weight influences these competitive results and rankings.

Beyond the Sinclair coefficient, previous studies have suggested that allometric scaling may be an appropriate method to account for the influence of body weight on OW performance (1,4,15,25). The goal of allometric scaling is to scale a variable by an individual's body weight raised to an exponent called the allometric parameter. This allometric parameter is specific to the test, providing researchers the flexibility to develop allometric parameters for specific performance tests. Previous studies have advocated for the use of allometric scaling over ratio scaling (dividing performance by body weight) due to the fact that body weight and performance do not always exhibit a linear relationship (4,12,14,20,21), one of the underlying assumptions for ratio scaling. Recently, Gillen (4) suggested that allometric scaling may be more appropriate than ratio scaling among senior level IWF competitors due to the lack of linear relationships between body weight and the snatch, clean & jerk, and combined total. Therefore, to understand if normalization via ratio scaling is appropriate to examine normalized performance in youth OW competitors, it is necessary to determine the model of best fit between OW performance and body weight. Therefore, the purpose of this study was to provide percentile rankings and comparisons for absolute OW performance for IWF World Championships youth competitors based on sex and weight class, and to provide percentile rankings and comparisons for allometrically scaled OW performance and Sinclair scores based on sex and weight class.

METHODS

Participants

Participants included youth Olympic weightlifters (n = 812, n = 398 boys, n = 414 girls) who participated in the IWF Youth World Championships in 2019, 2021, 2022, and 2023. Of note, these competitors were in the youth category, which spans ages 13-17-years. There is also a junior category, which spans ages 15-20-years, and senior category, which spans ages ≥ 15-years-old, however, results from the junior and senior category were not included in the present study. Boys were further divided into the following weight classes: 49 kg (n = 33), 55 kg (n = 50), 61 kg (n = 49), 67 kg (n = 47), 73 kg (n = 43), 81 kg (n = 38), 89 kg (n = 48), 96 kg (n = 26), 102 kg (n = 28), and 102+ kg (n = 36). Girls were further divided into the following weight classes: 40 kg (n = 35), 45 kg (n = 35), 49 kg (n = 52), 55 kg (n = 57), 59 kg (n = 51), 64 kg (n = 48), 71 kg (n = 49), 76 kg (n = 29), 81 kg (n = 28), and 81+ kg (n = 30). The Mississippi State University Institutional Review Board determined the data were considered exempt as the data are publicly accessible (10).

Research Design

The present study analyzed OW performance data for the IWF Youth World Championships from 2019, 2021, 2022, and 2023. Due to the COVID-19 pandemic, there were no data available for 2020. These data were used to examine absolute and allometrically scaled percentile rank scores for the snatch and clean & jerk exercises, as well as the highest total lifted for each lift combined. Furthermore, percentile rank scores were calculated for the Sinclair score results. Data were examined for boys and girls, as well as each weight class within boys and girls. The independent variables for the present study were sex and weight class, while the dependent variables were absolute and allometrically scaled weight lifted for the snatch, clean & jerk, total weight lifted, and Sinclair score.

Procedures

Data from the IWF Youth World Championships for 2019, 2021, 2022, and 2023 were compiled from competition results publicly available on the IWF website (10). For each lifter who completed at least one valid snatch and one valid clean & jerk, the best scores and totals were taken. Athletes were included only if they achieved a successful total (kg) in competition. Athletes who did not achieve at least one valid snatch and one valid clean & jerk were excluded.

Statistical Analyses

Descriptive statistics (mean, standard deviation, and percentile rankings) were computed for all absolute and allometrically scaled measures, as well as Sinclair scores. These rankings were presented by sex and weight class. Both boys and girls had 10 competitive weight classes each. Therefore, two-way analyses of variance (sex [boys vs. girls] x weight class [1 vs. 2 vs. 3 vs. 4 vs. 5 vs. 6 vs. 7 vs. 8 vs. 9 vs. 10]) with post hoc Bonferroni corrections examined sex and weight class differences. For boy's weight classes: 1 = 49 kg, 2 = 55 kg, 3 = 61 kg, 4 = 67 kg, 5 = 73 kg, 6 = 81 kg, 7 = 89 kg, 8 = 96 kg, 9 = 102 kg, and 10 = 102+ kg. For girl's weight classes: 1 = 40 kg, 2 = 45 kg, 3 = 49 kg, 4 = 55 kg, 5 = 59 kg, 6 = 64 kg, 7 = 71 kg, 8 = 76 kg, 9 = 81 kg, and 10 = 81+ kg.

The body weight versus absolute performance measures relationships were examined using polynomial regression analyses to examine the model of best fit to determine if allometric scaling was appropriate over ratio scaling. Using X = snatch, clean & jerk, and total, Y = body weight, and a_0, a_1, a_2, and a_3 = statistically determined regression coefficients, these models were:

$$Y = a_0 + a_1X \text{ (linear model)}$$
$$Y = a_0 + a_1X + a_2X^2 \text{ (quadratic model)}$$
$$Y = a_0 + a_1X + a_2X^2 + a_3X^3 \text{ (cubic model)}$$

The statistical significance ($p \leq 0.05$) for the increment in the proportion of variance that would be accounted for by a higher degree polynomial (i.e., *F*-test and R^2 change in SPSS) were determined using the *F*-test described by Pedhazur (22). For boys, the model of best fit for the relationship between body weight and absolute snatch, clean & jerk, and total were as follows: snatch – linear ($r^2 = 0.495$, $p < 0.001$), clean & jerk – quadratic ($r^2 = 0.496$, $p = 0.045$), total – quadratic ($r^2 = 0.506$, $p = 0.036$). For girls, the model of best fit for the relationship between body weight and absolute snatch, clean & jerk, and total were as follows: snatch – quadratic ($r^2 = 0.573$, $p < 0.001$), clean & jerk – cubic ($r^2 = 0.599$, $p = 0.019$), total – cubic ($r^2 = 0.603$, $p = 0.030$). Thus, all absolute performance metrics were normalized via allometric scaling instead of ratio scaling.

Each dependent variable (snatch, clean & jerk, and total) was allometrically scaled for body weight. The allometric scaling procedure involved the following equation:

$$a = \frac{T}{m^b}$$

Where a = allometric-scaled performance measure, T = absolute performance measure, m = body weight, and b = allometric parameter (12,26). The calculated allometric parameters (b) were taken as the slopes of the linear regression lines between log-transformed body weight and log-transformed performance measures (12,26). Additionally, the total weight lifted was used to compute Sinclair scores for each individual lifter using the Sinclair calculator published on the IWF's website (11).

Body mass normalization, either by allometric scaling or the Sinclair equation, should decrease the magnitude of relationships between body weight and performance. Therefore, Pearson product moment correlation coefficients evaluated the magnitudes of relationship between body weight and absolute performance measures, as well as body weight and body weight normalized performance measures. The following qualitative evaluations of the strength of association were made according to Mukaka (18) based on the absolute values of correlation coefficients: 0.90 to 1.00 = very high, 0.70 to 0.89

= high, 0.50 to 0.69 = moderate, 0.30 to 0.49 = low, and 0.00 to 0.29 = negligible. Statistical changes in the correlation coefficients before and after allometric scaling were calculated using z-score transformations from publicly available software (23). All other statistical analyses were performed in IBM SPSS v. 28 (Chicago, IL, USA). An alpha level of $p \leq 0.05$ was considered statistically significant. Calculations of effect sizes for analyses of variance were performed using partial η^2 such that an effect size of ≥ 0.14 was considered a large effect, ≥ 0.06 and < 0.14 was considered a moderate effect, ≥ 0.01 and < 0.06 was considered a small effect, and < 0.01 was considered a negligible effect. For follow-up independent t-tests for statistically significant interactions, Cohen's *d* effect sizes were calculated such that an effect size ≥ 0.80 was considered a large effect, ≥ 0.50 and < 0.80 was considered a moderate effect, ≥ 0.20 and < 0.50 was considered a small effect, and < 0.20 was considered a negligible effect.

RESULTS

Means, standard deviations, and percentile rankings for absolute and allometrically scaled results, as well as Sinclair scores, are presented in Tables 1-7. Calculated allometric parameters (b) are presented in Table 8.

For the boys, body weight exhibited high significant positive correlations with absolute snatch, clean & jerk, and total ($r \geq 0.700$, $p < 0.001$), negligible non-significant negative correlations with allometrically scaled snatch, clean & jerk, and total ($r \leq -0.074$, $p \geq 0.139$), and a negligible significant relationship with Sinclair scores ($r = -0.104$, $p = 0.038$). The correlation coefficients for the relationships between body weight and all performance measures significantly decreased with allometric scaling and Sinclair calculations (z-score ≥ 13.202, $p < 0.001$).

For the girls, body weight exhibited high significant positive correlations with absolute snatch, clean & jerk, and total ($r \geq 0.739$, $p < 0.001$), negligible non-significant negative correlations with allometrically scaled snatch, clean & jerk, and total ($r \leq -0.074$, $p \geq 0.133$), and a negligible non-significant relationship with Sinclair scores ($r = -0.033$, $p = 0.500$). The correlation coefficients for the relationships between body weight and all performance measures significantly decreased with allometric scaling and Sinclair calculations (z-score ≥ 14.162, $p < 0.001$).

There was a significant sex x weight class interaction for absolute snatch ($p < 0.001$, $\eta^2 = 0.100$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 2.738$). Within the boys, 49 < 55 < 61 < 67, 73 < 81, 89 < 96, 102, 102+ ($p \leq 0.013$, $d \geq 0.718$; note: 73 = 81, $p = 0.070$, $d = 0.557$; 81 and 89 = 102+, $p \geq 0.961$, $d \leq 0.352$). Within the girls, 40, 45 < 49 < 55, 59, 64 < 71 < 76, 81 < 81+ ($p \leq 0.024$, $d \geq 0.750$; note: 45 = 49 $p = 1.000$, $d = 0.298$; 59 and 64 = 71, $p \geq 0.141$, $d \leq 0.436$; 71 = 76, $p = 1.000$, $d = 0.499$; 76 and 81 = 81+, $p = 1.000$, $d \leq 0.307$).

There was a significant sex x weight class interaction for allometrically scaled snatch ($p < 0.001$, $\eta^2 = 0.047$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 3.408$). Within the boys 55, 61, 89, 102 > 49 and 102+ ($p \leq 0.001$, $d \geq 0.906$), while 67, 73, 81, 96 > 49, 55, and 102+ ($p \leq 0.009$, $d \geq 0.722$). Within the girls, 55, 59, 64, 71 > 81+ ($p \leq 0.049$, $d \geq 1.112$).

There was a significant sex x weight class interaction for absolute clean & jerk ($p < 0.001$, $\eta^2 = 0.071$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 2.921$). Within the boys, 49 < 55 < 61 < 67, 73 < 81, 89 < 96, 102, 102+ ($p \leq 0.015$, $d \geq 0.692$; note: 73 = 81, $p = 1.000$, $d = 0.536$; 89 = 96, $p = 1.000$, $d = 0.612$). Within the girls, 40, 45 < 49 < 55, 59, 64 < 71, 76, 81 < 81+ (p $p \leq 0.013$, $d \geq 0.881$; note: 45 = 49, $p = 1.000$, $d = 0.345$; 59, 64 = 71, $p \geq 0.067$, $d = 0.842$; 76, 81 = 81+, p = 1.000, $d \leq 0.393$).

There was a significant sex x weight class interaction for allometrically scaled clean & jerk ($p < 0.001$, $\eta^2 = 0.049$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 4.907$). Within the boys, 61, 67, 73, 81, 89, 96, 102 > 55 > 49, 102+ ($p \leq 0.037$, $d \geq 0.370$; note: 81 > 61, $p = 0.046$, $d = 0.320$; 67 > 102, $p = 0.049$, $d = 0.400$). Within the girls, 45, 49, 55, 59, 64, 71, 76, 81 > 40, 81+ ($p \leq 0.040$, $d \geq 0.648$; note: 40 = 45, 49, $p \geq 0.161$, $d \leq 0.356$).

There was a significant sex x weight class interaction for absolute total ($p < 0.001$, $\eta^2 = 0.087$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 2.915$). Within the boys, 49 < 55 < 61 < 67, 73 < 81, 89 < 96, 102, 102+ ($p \leq 0.014$, $d \geq 0.706$; note: 73 = 81, $p = 0.077$, $d = 0.557$; 81 = 102+, p = 0.449, $d = 0.459$). Within the girls, 40, 45 < 49 < 55, 59, 64 < 71, 76, 81 < 81+ ($p \leq 0.014$, $d \geq 1.098$; note: 45 = 49, $p = 1.000$, $d = 0.336$; 59, 64 = 71, $p \geq 0.073$, $d \leq 0.811$; 76, 81 =

Table 1. Percentile ranks, means, standard deviations (SDs), and n sizes for absolute snatch (kg) for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	74.95	65.60	69.55	70.00	84.00	96.40	101.90	93.60	111.35	114.50	105.50
10	81.00	70.00	74.30	87.00	92.60	100.40	104.80	108.60	112.70	120.00	110.70
15	90.00	71.10	79.30	91.00	95.20	103.00	105.85	110.00	118.35	123.35	115.00
20	94.00	72.00	83.00	93.00	100.60	103.80	109.20	110.80	126.20	124.80	115.80
25	98.00	72.50	84.75	95.00	104.00	107.00	111.50	114.25	129.50	126.25	120.00
30	102.00	73.20	87.30	97.00	105.00	108.00	115.00	116.40	131.10	127.70	122.30
35	105.00	74.90	90.85	99.00	106.60	108.80	117.65	119.15	132.45	130.00	125.00
40	109.00	76.00	92.00	101.00	111.00	111.20	118.60	121.60	133.00	130.60	129.20
45	111.00	76.60	92.00	103.00	112.00	114.60	120.55	123.05	135.15	132.05	130.65
50	114.00	78.00	93.50	104.00	114.00	115.00	122.00	124.00	136.50	133.00	131.50
55	117.00	78.70	94.05	105.00	115.40	118.00	125.00	125.00	139.55	133.00	135.00
60	120.00	79.00	95.00	106.00	116.00	120.40	129.60	128.40	141.00	135.40	135.20
65	123.00	80.10	96.15	108.50	117.40	123.00	132.35	130.85	141.55	136.85	136.05
70	125.30	81.00	97.70	110.00	120.00	125.60	133.30	132.60	142.90	139.40	137.90
75	130.00	82.50	98.00	111.50	121.00	130.00	134.75	136.00	144.00	148.00	139.75
80	133.00	84.20	99.80	112.00	121.00	130.20	140.20	140.20	144.60	151.20	142.20
85	136.00	85.90	102.00	113.00	121.80	132.00	142.00	141.00	145.00	153.95	144.00
90	141.00	87.60	103.00	114.00	123.40	133.00	143.00	144.10	147.30	156.10	147.30
95	145.00	92.90	105.45	119.50	127.60	135.60	145.10	148.55	151.25	160.85	150.15
Mean	112.97	77.97*	91.38*[1]	101.67*[1,2]	110.77*[1-3]	116.07*[1-3]	123.74*[1-4]	124.38*[1-5]	134.88*[1-7]	135.68*[1-7]	129.56*[1-5]
SD	21.37	7.24	10.68	13.15	12.19	13.50	14.05	14.87	11.49	13.23	14.55
n	398	33	50	49	47	43	38	48	26	28	36
Percentile	**All**	**40**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**81+**
5	53.00	34.20	51.20	42.40	60.80	57.20	55.90	66.00	64.00	73.15	76.65
10	55.50	44.20	54.60	55.00	63.00	65.00	65.60	70.00	70.00	77.90	79.10
15	60.00	46.60	55.00	56.95	65.00	65.80	69.35	72.00	75.00	80.35	80.65
20	63.00	50.00	56.00	57.60	66.00	67.40	70.00	75.00	80.00	81.80	82.40
25	65.00	51.00	57.00	60.25	67.00	68.00	72.25	76.50	82.00	82.00	84.00
30	67.00	52.00	57.80	61.00	68.00	70.60	73.70	77.00	84.00	82.70	85.30
35	68.25	53.00	58.60	62.55	69.30	72.00	74.00	78.00	84.50	83.00	86.00
40	70.00	53.00	59.40	64.00	70.00	74.00	75.00	81.00	86.00	84.20	86.40
45	72.00	53.00	61.00	65.00	70.10	74.00	76.00	81.00	86.50	85.05	87.95
50	74.00	54.00	62.00	65.50	71.00	75.00	76.00	82.00	88.00	86.50	90.00
55	76.00	54.80	62.00	66.00	71.90	76.60	77.00	83.00	88.00	87.00	91.05
60	77.00	55.00	62.00	67.00	72.00	77.20	78.00	84.00	89.00	90.00	92.60
65	79.00	56.60	63.00	68.00	74.00	78.80	80.85	84.00	90.00	90.85	94.00
70	82.00	59.40	64.20	68.00	75.60	80.00	82.30	85.00	90.00	92.00	94.70
75	83.00	62.00	66.00	68.75	76.00	81.00	84.00	87.50	90.50	92.00	95.00
80	85.00	62.00	67.00	69.40	77.00	82.00	85.20	88.00	91.00	94.20	95.80
85	88.00	65.40	67.00	72.00	78.00	82.00	88.00	90.00	93.50	95.65	97.05
90	91.00	67.40	68.80	73.00	78.20	83.80	89.30	92.00	96.00	98.40	99.90
95	94.00	71.20	71.20	73.70	79.30	88.00	93.00	92.50	100.00	102.55	105.35
Mean	73.60	54.74	61.09	63.42[1]	70.96[1-3]	74.57[1-3]	76.69[1-3]	81.00[1-4]	85.59[1-6]	87.36[1-6]	89.73[1-7]
SD	13.40	9.57	5.88	9.35	7.15	8.27	10.52	9.23	9.17	7.67	7.77
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 2. Percentile ranks, means, standard deviations (SDs), and n sizes for allometrically scaled snatch for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	7.64	7.34	7.33	6.97	7.99	8.72	8.57	7.72	8.62	8.50	6.74
10	8.27	7.83	7.79	8.65	8.81	9.04	8.89	8.83	8.73	9.04	7.30
15	8.66	8.02	8.31	9.07	9.04	9.27	8.99	8.93	9.07	9.15	7.62
20	8.86	8.06	8.68	9.22	9.57	9.33	9.32	9.04	9.92	9.28	7.96
25	9.05	8.13	9.04	9.41	9.83	9.65	9.66	9.24	10.01	9.53	8.12
30	9.27	8.22	9.19	9.61	9.87	9.69	9.81	9.45	10.15	9.60	8.22
35	9.47	8.39	9.54	9.85	10.02	9.85	10.01	9.58	10.36	9.72	8.38
40	9.65	8.51	9.62	10.04	10.41	10.05	10.25	9.71	10.42	9.79	8.58
45	9.82	8.57	9.75	10.18	10.53	10.27	10.35	9.84	10.44	9.89	8.62
50	9.95	8.71	9.82	10.38	10.72	10.35	10.46	10.01	10.53	9.92	8.66
55	10.11	8.80	9.91	10.41	10.84	10.54	10.65	10.08	10.79	9.99	8.68
60	10.34	8.83	10.04	10.55	10.90	10.77	10.92	10.39	10.92	10.08	8.78
65	10.47	8.94	10.12	10.73	11.06	11.01	11.17	10.56	10.96	10.32	8.94
70	10.67	9.09	10.22	10.87	11.29	11.34	11.32	10.91	11.02	10.57	9.02
75	10.91	9.22	10.28	11.04	11.34	11.61	11.43	11.00	11.05	11.09	9.25
80	11.09	9.40	10.45	11.09	11.40	11.67	11.85	11.27	11.14	11.20	9.34
85	11.29	9.61	10.66	11.22	11.46	11.78	11.95	11.55	11.26	11.38	9.59
90	11.53	9.79	10.77	11.29	11.56	11.88	12.13	11.76	11.34	11.62	9.68
95	11.88	10.44	11.05	11.80	11.96	12.10	12.29	12.06	11.58	11.95	9.94
Mean	9.92	8.73*	9.60*[1,10]	10.09*[1,10]	10.43*[1,2,10]	10.42*[1,2,10]	10.52*[1,2,10]	10.08*[1,10]	10.44*[1,2,10]	10.14*[1,10]	8.59*
SD	1.26	0.81	1.09	1.28	1.11	1.18	1.16	1.21	0.86	0.97	0.94
n	398	33	50	49	47	43	38	48	26	28	36

Percentile	All	40	45	49	55	59	64	71	76	81	81+
5	4.91	3.78	5.25	4.11	5.59	4.99	4.61	5.17	4.80	5.30	4.63
10	5.43	4.81	5.58	5.32	5.71	5.61	5.42	5.45	5.24	5.66	4.79
15	5.61	5.08	5.64	5.53	5.91	5.73	5.74	5.69	5.73	5.75	5.05
20	5.72	5.46	5.69	5.70	5.97	5.88	5.89	5.89	5.96	5.87	5.15
25	5.85	5.55	5.81	5.83	6.05	5.93	6.01	5.97	6.18	5.90	5.34
30	5.94	5.68	5.88	5.91	6.12	6.13	6.08	6.00	6.26	5.95	5.35
35	6.02	5.75	5.95	6.06	6.24	6.24	6.10	6.05	6.29	6.03	5.37
40	6.10	5.78	6.04	6.18	6.32	6.39	6.21	6.24	6.36	6.11	5.43
45	6.24	5.80	6.21	6.28	6.39	6.44	6.24	6.32	6.47	6.23	5.45
50	6.30	5.88	6.28	6.37	6.44	6.53	6.33	6.39	6.55	6.25	5.53
55	6.39	5.95	6.31	6.45	6.49	6.65	6.42	6.45	6.60	6.33	5.61
60	6.45	5.98	6.38	6.48	6.55	6.75	6.47	6.52	6.69	6.44	5.72
65	6.53	6.02	6.44	6.56	6.71	6.88	6.66	6.60	6.74	6.48	5.89
70	6.63	6.21	6.52	6.58	6.82	6.94	6.80	6.69	6.76	6.57	6.02
75	6.76	6.30	6.70	6.66	6.93	7.06	6.91	6.80	6.76	6.62	6.06
80	6.87	6.42	6.82	6.75	6.94	7.11	7.02	6.89	6.81	6.72	6.14
85	6.95	6.69	6.86	6.96	7.02	7.14	7.24	7.04	6.99	6.87	6.26
90	7.10	6.86	7.01	7.05	7.07	7.33	7.39	7.12	7.17	7.07	6.29
95	7.30	7.23	7.25	7.21	7.14	7.60	7.69	7.25	7.46	7.32	6.62
Mean	6.24	5.83	6.23	6.15	6.43[10]	6.48[10]	6.34[10]	6.32[10]	6.41	6.29	5.62
SD	0.76	0.89	0.60	0.90	0.62	0.71	0.86	0.70	0.67	0.53	0.55
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 3. Percentile ranks, means, standard deviations (SDs), and n sizes for absolute clean & jerk (kg) for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	94.90	81.50	86.40	90.50	105.00	116.00	120.00	119.00	122.45	144.50	128.40
10	102.00	85.00	93.20	110.00	116.40	121.60	127.30	132.70	140.30	150.00	136.00
15	112.00	90.00	99.95	113.50	119.20	124.60	133.00	135.35	150.00	151.70	141.40
20	116.00	90.80	103.20	116.00	125.60	129.60	135.00	140.60	154.00	153.00	148.80
25	120.00	92.00	107.75	118.00	129.00	132.00	140.00	144.25	160.00	153.25	150.25
30	125.00	93.00	110.60	119.00	131.00	134.20	144.70	145.70	160.10	154.70	156.40
35	130.00	94.80	114.70	121.00	132.60	135.40	145.65	148.30	161.90	155.00	160.00
40	134.60	95.00	115.00	123.00	135.00	140.00	149.80	151.80	163.80	158.00	160.80
45	136.00	96.30	115.00	127.00	136.00	142.40	151.00	154.05	166.15	160.00	162.65
50	143.50	98.00	116.00	130.00	139.00	145.00	153.50	155.00	167.50	160.50	165.50
55	146.00	98.00	116.05	130.50	143.80	146.20	155.45	156.95	168.85	161.00	167.35
60	150.00	98.80	117.60	133.00	145.00	149.40	157.20	160.00	170.20	164.20	168.20
65	153.00	101.00	119.00	134.00	146.20	154.00	161.00	160.00	172.10	166.00	169.05
70	156.00	101.80	120.70	135.00	147.00	156.80	161.00	162.50	175.70	167.30	171.80
75	160.00	103.50	122.25	136.00	148.00	158.00	162.50	167.50	177.00	169.50	172.00
80	161.00	105.20	124.00	140.00	149.40	158.00	168.00	170.00	178.20	173.80	173.60
85	167.15	108.70	125.00	143.00	150.80	158.40	169.75	171.00	179.00	185.00	174.00
90	171.00	112.60	125.00	145.00	153.80	161.00	175.40	176.40	180.00	191.90	176.20
95	179.00	117.30	128.25	147.50	159.20	167.80	180.05	182.55	185.85	202.75	182.35
Mean	139.67	98.12*	113.58*[1]	126.55*[1,2]	137.13*[1-3]	143.33*[1-3]	152.18*[1-4]	154.42*[1-5]	164.69*[1-6]	164.57*[1-6]	160.53*[1-7]
SD	25.55	9.72	12.61	15.53	15.04	16.41	16.62	17.58	15.94	15.64	18.01
n	398	33	50	49	47	43	38	48	26	28	36
Percentile	**All**	**40**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**81+**
5	64.00	42.80	61.80	48.00	73.00	73.40	63.70	83.50	80.50	92.70	97.10
10	70.00	54.00	67.20	64.30	79.00	80.00	79.70	88.00	95.00	96.90	100.20
15	74.00	60.80	69.00	69.85	81.70	81.80	88.00	92.00	96.50	99.35	103.30
20	78.00	62.00	70.00	72.60	83.00	85.00	89.00	95.00	97.00	100.80	105.20
25	81.00	63.00	70.00	74.00	83.00	85.00	90.00	95.50	100.00	103.25	106.00
30	83.00	63.00	70.80	76.80	84.40	86.60	91.70	97.00	103.00	104.70	107.00
35	85.00	64.60	72.20	78.00	86.30	89.20	93.00	98.50	106.00	107.15	107.00
40	88.00	65.40	74.00	80.00	88.00	90.80	95.20	100.00	106.00	108.00	107.40
45	90.00	66.00	74.20	80.00	89.00	92.00	97.00	100.50	107.50	108.05	108.00
50	92.00	67.00	75.00	81.50	89.00	93.00	98.00	101.00	108.00	109.50	109.00
55	95.00	67.80	75.00	82.15	90.00	93.60	99.90	102.50	109.50	110.00	109.05
60	97.00	70.00	76.60	83.00	91.80	95.20	100.40	103.00	110.00	114.00	111.20
65	100.00	70.40	78.80	83.45	92.00	97.60	101.00	104.00	113.50	114.85	113.30
70	101.00	71.40	80.00	85.00	93.00	100.00	103.00	105.00	116.00	115.30	115.70
75	104.00	74.00	81.00	85.75	95.00	100.00	105.00	106.50	116.00	116.75	119.25
80	107.00	76.60	82.00	86.00	96.00	100.60	106.20	107.00	117.00	118.00	120.80
85	108.75	81.60	83.00	88.00	97.00	103.00	107.65	110.50	119.50	121.25	124.35
90	113.00	83.00	83.40	90.00	98.00	105.60	112.10	113.00	121.00	123.40	125.90
95	119.00	84.20	85.00	93.00	100.00	107.00	116.55	120.50	125.50	128.10	134.50
Mean	91.66	67.43	74.83	78.40[1]	88.60[1-3]	92.39[1-3]	96.25[1-3]	100.88[1-4]	107.66[1-6]	110.14[1-6]	111.97[1-7]
SD	17.17	11.24	7.70	12.35	9.02	9.69	13.92	10.45	11.89	9.59	9.97
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 4. Percentile ranks, means, standard deviations (SDs), and n sizes for allometrically scaled clean & jerk for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	10.50	9.93	9.94	9.81	10.91	11.54	11.24	10.64	10.50	11.91	9.42
10	11.27	10.41	10.69	12.13	12.07	12.06	11.87	12.07	12.18	12.38	10.06
15	11.75	11.01	11.47	12.33	12.41	12.37	12.60	12.29	12.87	12.49	10.61
20	12.24	11.09	12.13	12.60	13.12	12.93	13.05	12.67	13.19	12.70	10.77
25	12.43	11.25	12.37	12.83	13.42	13.07	13.21	12.85	13.69	12.73	11.05
30	12.73	11.36	12.69	12.99	13.57	13.25	13.79	13.08	13.81	12.78	11.40
35	12.98	11.55	13.15	13.25	13.71	13.48	13.80	13.28	13.93	12.95	11.53
40	13.22	11.61	13.22	13.38	13.94	13.83	14.05	13.50	14.06	13.11	11.62
45	13.34	11.77	13.26	13.83	14.06	14.09	14.19	13.75	14.25	13.24	11.80
50	13.65	11.96	13.31	14.12	14.31	14.37	14.42	13.88	14.36	13.27	12.11
55	13.83	11.98	13.36	14.26	14.88	14.49	14.54	13.98	14.46	13.40	12.28
60	14.03	12.13	13.53	14.41	14.99	14.82	14.73	14.19	14.53	13.70	12.34
65	14.23	12.33	13.66	14.61	15.11	15.15	14.97	14.32	14.69	13.83	12.40
70	14.42	12.41	13.83	14.75	15.14	15.42	15.01	14.74	15.01	14.05	12.66
75	14.72	12.65	14.04	14.80	15.26	15.51	15.11	14.99	15.18	14.11	12.89
80	15.05	12.82	14.21	15.25	15.43	15.58	15.62	15.23	15.25	14.49	13.07
85	15.28	13.28	14.30	15.53	15.60	15.66	15.86	15.41	15.29	15.26	13.31
90	15.60	13.79	14.31	15.69	15.88	15.84	16.36	16.02	15.43	15.87	13.36
95	16.12	14.34	14.70	16.07	16.47	16.50	16.92	16.48	15.87	16.66	13.84
Mean	13.53	11.99*	13.06*[1,10]	13.77*[1,2,10]	14.20*[1,2,10]	14.17*[1,2,10]	14.28*[1-3,10]	13.84*[1,2,10]	14.12*[1,2,10]	13.64*[1,2,10]	11.87*
SD	1.67	1.19	1.40	1.67	1.51	1.57	1.51	1.58	1.34	1.28	1.36
n	398	33	50	49	47	43	38	48	26	28	36
Percentile	**All**	**40**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**81+**
5	5.61	4.29	5.69	4.20	6.07	5.76	4.72	5.84	5.48	5.92	5.24
10	6.10	5.34	6.25	5.63	6.52	6.23	5.94	6.24	6.39	6.32	5.46
15	6.32	6.04	6.38	6.14	6.64	6.35	6.53	6.49	6.41	6.41	5.58
20	6.43	6.16	6.43	6.34	6.72	6.66	6.64	6.59	6.59	6.58	5.64
25	6.55	6.23	6.49	6.51	6.81	6.67	6.69	6.64	6.75	6.63	5.76
30	6.65	6.28	6.53	6.71	6.93	6.84	6.81	6.73	6.85	6.69	5.84
35	6.73	6.40	6.67	6.86	7.01	6.97	6.88	6.92	7.02	6.90	6.03
40	6.85	6.47	6.81	6.98	7.15	7.05	7.12	6.98	7.05	6.96	6.12
45	6.98	6.54	6.85	7.02	7.22	7.15	7.19	7.07	7.19	7.00	6.16
50	7.06	6.57	6.90	7.12	7.30	7.29	7.24	7.10	7.29	7.09	6.28
55	7.16	6.61	6.98	7.22	7.37	7.36	7.41	7.14	7.31	7.17	6.36
60	7.25	6.63	7.05	7.25	7.47	7.43	7.45	7.20	7.36	7.27	6.37
65	7.33	6.82	7.25	7.28	7.50	7.59	7.46	7.25	7.54	7.33	6.44
70	7.42	6.90	7.41	7.42	7.65	7.75	7.63	7.27	7.67	7.40	6.50
75	7.51	6.96	7.46	7.51	7.77	7.81	7.75	7.37	7.79	7.43	6.64
80	7.68	7.22	7.56	7.63	7.79	7.83	7.92	7.42	7.89	7.51	6.65
85	7.80	7.52	7.63	7.69	7.87	8.06	8.01	7.73	7.99	7.73	6.72
90	7.89	7.64	7.74	7.85	7.96	8.26	8.27	7.89	8.08	7.91	6.88
95	8.16	7.81	7.85	8.11	8.13	8.35	8.60	8.42	8.35	8.15	7.32
Mean	6.98	6.51	6.91[10]	6.87[10]	7.23[1,10]	7.22[1,10]	7.14[1,10]	7.05[1,10]	7.20[1,10]	7.07[10]	6.21
SD	0.86	0.94	0.71	1.08	0.70	0.74	1.02	0.71	0.77	0.59	0.55
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 5. Percentile ranks, means, standard deviations (SDs), and n sizes for absolute total (kg) for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	170.00	146.50	156.40	161.00	190.20	214.40	224.85	212.30	233.80	261.35	234.75
10	183.00	154.60	166.60	199.00	207.20	222.20	227.90	239.90	255.80	272.00	249.80
15	201.85	161.20	180.55	204.00	216.60	226.20	240.55	245.35	268.15	274.40	255.95
20	211.00	163.80	187.20	208.00	225.60	236.00	244.60	252.80	278.20	278.60	265.00
25	220.00	165.50	194.50	213.50	233.00	238.00	250.75	259.00	289.75	280.25	269.50
30	227.00	169.00	200.60	216.00	236.40	240.60	259.50	264.10	292.30	282.40	281.00
35	236.00	170.80	204.85	220.00	240.80	245.20	266.90	271.00	296.80	284.05	281.95
40	242.20	172.60	208.40	229.00	247.20	252.20	270.60	272.20	299.80	290.00	293.60
45	250.00	173.30	209.00	231.00	249.20	255.00	272.10	276.05	300.00	292.05	295.65
50	256.00	174.00	210.50	231.00	252.00	258.00	273.50	279.00	302.50	293.50	298.50
55	263.00	176.40	211.05	235.50	255.40	264.60	277.80	280.95	310.10	294.95	300.00
60	270.00	179.40	212.00	239.00	261.60	271.40	288.00	284.40	313.00	295.80	302.60
65	276.00	180.00	214.00	242.00	264.40	278.60	290.40	290.55	314.10	301.25	309.00
70	281.00	182.40	215.70	247.00	267.00	281.00	293.30	297.50	316.80	308.00	309.00
75	289.00	183.50	221.25	249.50	268.00	287.00	299.75	304.75	317.00	316.50	310.00
80	295.00	185.60	222.80	253.00	269.40	287.20	308.20	307.00	320.60	328.40	314.20
85	304.15	194.30	223.35	254.50	270.80	289.40	310.60	316.95	324.90	335.95	315.45
90	313.00	200.60	227.90	258.00	277.20	291.00	316.60	321.10	326.60	348.70	318.60
95	322.00	209.50	231.80	263.50	285.20	304.60	323.25	325.20	337.10	362.70	333.20
Mean	252.65	176.09*	204.96*[1]	228.22*[1,2]	247.89*[1-3]	259.40*[1-3]	275.92*[1-4]	278.79*[1-5]	299.58*[1-7]	300.25*[1-7]	290.08*[1-5]
SD	46.52	16.26	22.72	28.13	26.49	29.35	29.97	31.84	26.82	27.91	31.68
n	398	33	50	49	47	43	38	48	26	28	36
Percentile	**All**	**40**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**81+**
5	116.00	77.00	113.80	90.40	136.50	133.00	119.60	151.50	145.50	167.20	174.10
10	125.50	100.60	121.00	120.30	141.60	146.20	148.00	159.00	167.00	177.80	180.40
15	135.00	108.20	125.40	124.85	147.40	149.60	156.40	166.00	170.00	181.00	185.30
20	141.00	113.20	126.40	131.00	150.00	151.00	160.80	168.00	178.00	181.80	187.60
25	146.00	114.00	129.00	135.25	151.50	154.00	163.00	173.00	182.50	183.00	191.50
30	150.00	115.00	130.00	139.00	153.00	156.60	165.70	174.00	190.00	188.80	192.30
35	154.00	116.00	132.00	141.55	154.00	161.00	167.00	177.50	191.00	190.15	193.00
40	159.00	117.40	133.80	143.20	159.00	164.40	169.20	181.00	191.00	191.00	196.40
45	162.00	118.20	135.20	145.70	160.10	167.00	173.05	182.00	193.00	193.10	198.90
50	166.00	120.00	136.00	146.50	161.00	169.00	174.50	184.00	198.00	195.00	199.00
55	170.00	124.00	137.00	147.15	162.00	170.00	176.95	185.00	199.50	199.75	200.05
60	174.00	125.60	139.80	149.60	163.80	174.00	179.40	185.00	200.00	202.20	202.20
65	178.00	127.40	142.40	151.45	165.70	175.00	181.00	188.00	201.50	204.85	203.75
70	182.00	129.80	144.00	152.10	168.60	178.80	183.30	191.00	204.00	207.30	208.70
75	187.00	136.00	145.00	153.75	170.50	181.00	188.50	194.00	204.50	210.25	213.00
80	191.00	142.60	146.80	154.80	171.40	182.60	190.20	195.00	208.00	212.40	219.00
85	196.75	145.60	148.00	160.05	172.30	185.40	194.65	198.50	212.50	214.65	220.35
90	203.00	148.80	151.20	162.40	175.40	187.80	203.10	202.00	221.00	221.80	224.60
95	212.00	155.20	155.00	165.35	178.40	195.00	208.75	213.00	223.50	230.65	237.65
Mean	165.26	122.17	135.91	141.83[1]	159.56[1-3]	166.96[1-3]	172.94[1-3]	181.88[1-4]	193.24[1-6]	197.50[1-6]	201.70[1-7]
SD	30.28	20.49	12.72	21.44	15.67	17.58	24.07	19.19	20.55	16.84	16.84
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 6. Percentile ranks, means, standard deviations (SDs), and n sizes for allometrically scaled total for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	18.05	17.24	17.34	16.86	18.96	20.45	20.15	18.52	19.16	20.57	16.14
10	19.86	18.12	18.35	20.82	20.61	21.11	20.33	20.56	20.98	21.39	17.57
15	20.39	18.92	19.91	21.44	21.68	21.49	21.66	21.33	21.77	21.73	18.03
20	21.00	19.31	20.77	21.88	22.71	22.46	22.28	21.73	23.17	21.86	18.82
25	21.52	19.46	21.79	22.28	23.09	22.75	23.28	22.15	23.68	22.41	19.53
30	21.97	19.91	22.17	22.54	23.48	23.09	23.58	22.62	24.16	22.51	19.66
35	22.49	20.11	22.53	23.06	24.00	23.24	24.15	23.05	24.51	22.61	20.09
40	22.94	20.28	22.97	23.88	24.42	23.89	24.30	23.25	24.57	22.87	20.28
45	23.20	20.36	23.09	24.04	24.74	24.20	24.56	23.37	24.61	23.14	20.42
50	23.47	20.49	23.30	24.22	25.01	24.33	24.58	23.69	24.81	23.19	20.62
55	23.92	20.71	23.37	24.63	25.35	25.15	24.86	24.09	25.14	23.25	20.89
60	24.31	21.02	23.41	25.03	25.85	25.74	25.74	24.34	25.45	23.52	21.02
65	24.57	21.11	23.57	25.24	26.27	26.22	26.09	25.21	25.63	24.31	21.15
70	25.06	21.38	23.85	25.75	26.42	26.56	26.13	25.82	25.72	24.56	21.67
75	25.72	21.58	24.34	26.06	26.59	27.04	26.65	25.97	26.13	25.24	21.95
80	26.12	21.77	24.50	26.43	26.63	27.11	27.53	26.46	26.33	25.90	22.38
85	26.48	22.83	24.58	26.55	26.89	27.31	27.65	27.02	26.48	26.40	22.89
90	27.10	23.57	25.05	26.83	27.41	27.43	28.18	27.57	26.69	27.54	23.01
95	27.71	24.71	25.52	27.47	28.18	28.68	29.25	28.26	27.42	28.45	23.69
Mean	23.43	20.69*	22.64*[1,10]	23.84*[1,10]	24.61*[1,2,10]	24.57*[1,2,10]	24.79*[1,2,10]	23.90*[1,10]	24.54*[1,2,10]	23.77*[1,10]	20.43*
SD	2.87	1.90	2.43	2.90	2.54	2.69	2.61	2.73	2.14	2.17	2.23
n	398	33	50	49	47	43	38	48	26	28	36
Percentile	**All**	**40**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**81+**
5	10.68	8.07	10.96	8.29	11.77	10.89	9.30	11.17	10.30	11.24	9.87
10	11.51	10.39	11.77	11.03	12.15	11.97	11.59	11.86	11.65	12.18	10.34
15	11.87	11.19	12.15	11.50	12.62	12.30	12.28	12.26	12.23	12.30	10.62
20	12.21	11.72	12.25	12.22	12.81	12.55	12.61	12.51	12.46	12.40	10.92
25	12.40	11.86	12.39	12.46	12.96	12.70	12.76	12.64	12.94	12.47	11.12
30	12.66	11.97	12.52	12.75	13.05	12.85	12.85	12.88	13.29	12.72	11.47
35	12.81	12.04	12.78	12.95	13.09	13.14	12.96	13.00	13.36	12.95	11.51
40	12.98	12.17	12.88	13.23	13.52	13.39	13.26	13.22	13.39	13.03	11.53
45	13.15	12.25	13.03	13.33	13.70	13.67	13.52	13.36	13.61	13.15	11.59
50	13.36	12.39	13.25	13.42	13.79	13.84	13.57	13.49	13.98	13.32	11.79
55	13.54	12.43	13.28	13.50	13.90	14.10	13.78	13.58	13.99	13.50	11.85
60	13.73	12.71	13.46	13.66	14.07	14.22	13.96	13.67	14.07	13.58	12.09
65	13.88	12.93	13.76	13.84	14.23	14.32	14.11	13.78	14.11	13.77	12.16
70	14.05	13.12	13.86	13.93	14.38	14.56	14.29	14.03	14.23	13.96	12.27
75	14.23	13.28	13.92	14.05	14.52	14.73	14.63	14.20	14.53	14.15	12.59
80	14.41	13.76	14.24	14.47	14.64	15.05	14.77	14.23	14.73	14.25	12.75
85	14.69	14.12	14.27	14.69	14.75	15.22	15.27	14.52	14.90	14.44	13.03
90	14.99	14.36	14.58	14.95	14.92	15.43	15.75	15.00	15.42	14.97	13.16
95	15.42	14.98	14.99	15.11	15.24	15.88	16.33	15.66	15.72	15.46	13.86
Mean	13.21	12.33	13.13	13.02	13.65[10]	13.70[10]	13.49[10]	13.37	13.61[10]	13.36	11.82
SD	1.59	1.79	1.23	1.96	1.28	1.41	1.85	1.38	1.41	1.08	1.05
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 7. Percentile ranks, means, standard deviations (SDs), and n sizes for Sinclair scores for boys (top) and girls (bottom) by weight class (kg).

Percentile	All	49	55	61	67	73	81	89	96	102	102+
5	272.33	267.09	260.44	247.11	274.58	293.77	288.12	264.92	275.90	298.78	250.99
10	294.26	279.98	274.90	305.74	298.29	303.13	290.61	294.26	302.08	310.69	269.63
15	305.33	292.55	298.26	314.59	314.25	308.51	309.70	305.20	314.04	315.50	276.74
20	312.65	299.39	311.18	320.89	329.06	322.18	318.87	311.04	332.77	317.49	285.49
25	317.93	301.18	329.45	326.87	336.60	326.71	333.07	317.26	341.07	325.03	295.86
30	325.59	308.38	332.46	330.69	339.31	331.32	337.35	323.66	348.02	325.76	298.12
35	330.67	311.73	337.19	339.40	347.26	334.60	345.26	330.49	352.52	326.86	302.28
40	334.86	313.84	344.08	350.02	352.89	342.88	347.39	332.84	353.34	332.36	311.49
45	338.13	315.09	345.63	352.34	357.89	347.42	351.16	334.97	354.31	335.77	314.17
50	345.52	317.08	349.31	354.84	361.93	348.96	351.82	339.57	357.25	336.06	316.59
55	349.85	320.46	350.22	361.65	366.71	361.05	355.53	345.14	362.70	338.11	322.02
60	353.00	324.59	351.02	366.54	373.61	369.45	367.97	348.38	367.03	340.57	323.14
65	359.51	326.20	353.15	371.12	379.79	376.02	373.02	360.62	369.55	351.02	324.66
70	366.55	330.42	357.81	377.70	381.86	381.08	373.56	369.40	370.59	355.71	325.75
75	371.92	333.65	364.27	382.31	384.47	387.89	380.90	372.08	375.93	365.14	330.89
80	377.68	337.22	366.65	387.42	385.03	388.78	393.53	378.55	379.30	376.01	333.99
85	383.84	353.18	367.87	389.48	389.25	391.72	395.23	387.37	381.45	383.46	338.30
90	390.88	364.57	374.75	393.10	396.01	393.44	402.88	394.76	384.60	399.60	344.90
95	401.06	383.06	382.18	402.76	407.71	411.33	418.27	404.03	395.19	413.61	352.93
Mean	342.94	320.23*	339.53*[10]	349.83*[1,10]	356.16*[1,10]	352.58*[1,10]	354.44*[1,10]	342.25*[10]	353.36*[1,10]	344.74*[10]	310.24*
SD	38.53	29.42	35.99	42.30	36.41	38.41	37.26	39.09	30.96	31.56	32.36
n	398	33	50	49	47	43	38	48	26	28	36

Percentile	All	40	45	49	55	59	64	71	76	81	81+
5	188.73	146.49	191.63	142.64	199.61	183.63	156.54	188.68	175.01	193.21	187.48
10	200.36	187.22	206.61	189.75	206.32	201.63	195.01	200.00	198.39	209.13	193.68
15	207.01	201.75	212.79	198.03	213.75	207.23	206.59	207.23	207.13	210.29	196.52
20	212.24	211.30	214.52	210.60	216.97	211.71	212.18	210.78	212.16	212.31	200.54
25	214.42	214.32	216.32	215.90	219.73	214.38	214.75	213.62	219.70	214.26	201.87
30	217.53	215.45	218.75	219.57	221.12	216.54	216.19	217.04	226.21	218.16	203.78
35	219.85	216.10	223.72	222.65	221.72	221.34	218.10	219.60	227.60	222.65	209.69
40	222.99	217.56	225.21	228.06	228.87	225.60	223.08	223.49	227.82	223.14	212.17
45	226.55	219.42	227.70	229.23	231.84	230.36	227.55	225.60	231.29	225.00	212.94
50	228.76	222.17	231.92	230.54	233.38	233.59	228.46	228.08	237.63	228.12	215.40
55	231.18	223.85	232.64	232.62	235.35	237.93	231.88	229.50	238.20	231.17	218.28
60	233.54	227.10	235.55	234.60	238.94	239.61	234.95	230.26	239.09	233.53	219.07
65	237.20	229.99	240.73	237.73	241.20	241.42	237.47	233.06	240.14	236.75	223.06
70	239.86	232.81	242.25	239.50	243.45	245.58	240.48	237.22	242.44	239.98	225.09
75	242.48	239.86	242.92	241.55	245.79	248.22	246.20	239.76	247.18	243.26	226.75
80	247.34	242.25	249.12	249.66	247.87	253.86	248.56	240.54	250.11	244.89	229.78
85	250.34	246.78	250.35	252.37	249.74	256.62	256.88	245.54	253.03	248.02	230.71
90	255.92	251.89	255.03	257.91	252.62	260.10	265.11	253.70	262.63	257.08	232.26
95	262.26	261.66	262.29	260.91	258.13	267.60	274.75	264.41	267.28	265.93	253.62
Mean	226.82	220.06	229.71	224.09	231.23	230.93	226.93	225.79	231.37	229.22	215.54
SD	25.73	30.24	21.45	33.68	21.43	23.80	31.19	23.32	24.05	18.82	16.92
n	414	35	35	52	57	51	48	49	29	28	30

**Indicates greater than other sex. [1]49 kg for boys, 40 kg for girls; [2]55 kg for boys, 45 kg for girls; [3]61 kg for boys, 49 kg for girls; [4]67 kg for boys, 55 kg for girls; [5]73 kg for boys, 59 kg for girls; [6]81 kg for boys, 64 kg for girls; [7]89 kg for boys, 71 kg for girls; [8]96 kg for boys, 76 kg for girls; [9]102 kg for boys, 81 kg for girls; [10]102+ kg for boys, 81+ kg for girls. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

Table 8. Calculated lift-specific allometric parameters (*b*) for boys and girls.

Lift	Boys	Girls
Snatch	0.5636	0.6014
Clean & Jerk	0.5410	0.6276
Total	0.5511	0.6157

81+, $p = 1.000$, $d \leq 0.450$).

There was a significant sex x weight class interaction for allometrically scaled total ($p < 0.001$, $\eta^2 = 0.050$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 4.529$). Within the boys, 61, 67, 73, 81, 89, 96, 102 > 49, 55, 102+ ($p \leq 0.007$, $d \geq 0.830$; note: 55 = 61, $p = 0.173$, $d = 0.449$; 89, 102 = 55, $p \geq 0.112$, $d \leq 0.491$). Within the girls, 59, 64, 76 > 81+ ($p \leq 0.024$, $d \geq 1.110$).

There was a significant sex x weight class interaction for Sinclair scores ($p < 0.012$, $\eta^2 = 0.026$). The boys were stronger than the girls across all weight classes ($p < 0.001$, $d \geq 3.668$). Within the boys, 55, 61, 67, 73, 81, 89, 96, 102 > 49, 102+ ($p \leq 0.003$, $d \geq 1.097$; note: 49 = 55, $p = 0.274$, $d = 0.587$; 89, 102 = 49, $p \geq 0.086$, $d \leq 0.803$). Within the girls there were no differences across weight class ($p = 1.000$, $d \leq 0.761$).

DISCUSSION

This study is the first to provide percentile rank values for absolute, allometrically scaled, and Sinclair scored OW performance in youth competitors with the weight classes implemented in 2018 by the IWF. The polynomial regression analyses in the present study, in conjunction with the decrease in relationships between body weight and OW performance measures after allometric scaling, suggest that allometric scaling is more appropriate than ratio scaling, since ratio scaling necessarily infers a linear relationship between body weight and absolute snatch, clean & jerk, and total weightlifting scores. Furthermore, the present study demonstrates weight class- and sex-specific differences for absolute, allometrically scaled, and Sinclair scored OW results, which may provide further insight regarding the role that body weight plays in elite level youth weightlifting performance. Specifically, body weight, particularly lean body mass, plays a crucial role in maximal strength capabilities. However, body weight must be considered in addition to other anthropometric characteristics, such as height and limb length, to maximize physical performance based on athlete size. Thus, a better understanding of the impact body weight has on OW performance may aid coaches and competitors in choosing the appropriate weight class, particularly in youth where there are biological maturation factors that occur during growth and development. Coaches and competitors may use the percentile rankings and allometric scaling parameters from the present study to assess absolute and normalized weightlifting results for elite level youth Olympic Weightlifters, or for those desiring to compete at this level.

No previous studies have published percentile rank values for IWF youth competitors, though one previous study has published these values for IWF senior competitors (4). Coaches of IWF youth competitors, as well as competitors themselves, are well aware of current records and competitive results from those they are competing against, however, it may prove beneficial to have published percentile rankings by which performance may be compared against in preparation for competition. In light of this, the present study provides percentile rankings for the snatch, clean & jerk, and total from IWF Youth World Championships competitors, broken down by weight class and sex. Additionally, the present results present percentile rankings for allometrically scaled results for the snatch, clean & jerk, and total, as well as Sinclair scores, which may be beneficial for coaches and competitors in deciding the most appropriate weight class for optimal performance. Thus, the present study provides objective metrics by which coaches and competitors may compare their youth OW performance for current or aspiring youth competitors.

It is typical to normalize performance measures by examining the ratio of absolute performance to body weight, known as ratio scaling, to account for the influence of body weight on absolute performance differences. However, an assumption of ratio scaling is a linear relationship between the performance metric and body weight (12,19,20). To examine this, the present study utilized polynomial regression

analyses to determine the model of best fit for the relationships between absolute snatch, clean & jerk, and total results and body weight. For boys, only snatch and body weight exhibited a linear model of best fit, while for the girls all relationships between absolute measures and body weight were quadratic or cubic, which suggests that ratio scaling is not the most appropriate normalization technique. In place of this, allometric scaling was used, which was further supported by the decrease in correlation coefficients, in terms of significance and magnitude, for the relationships between allometrically scaled measures and body weight.

Previous studies have examined the influence of body weight on OW performance in youth, suggesting that increases in body weight tend to yield superior OW performance (2,8). However, in their examination of the influence of body weight on OW performance, Huebner and Perperoglou (8) noted that body weight may be a more influential factor on OW performance after the growth and development process, suggesting that performance for youth OW competitors may not be as affected by increases in body mass. This is likely accounted for by the significant changes in hormonal function and neuromuscular adaptations across growth and development which yield significant increases in muscle mass and subsequent muscle strength (2,5). In the present study, absolute OW performance was generally greater with heavier weight classes, while boys were stronger than girls across all weight classes. This is relatively unsurprising as competitors in heavier weight classes, even among youth, likely have greater muscle mass, leading to greater strength and power output (3,4,8,9,14). When allometrically scaled, for boys and girls the middle weight classes tended to yield superior performance than the heaviest and lightest weight classes, suggesting that competitors on either end of the weight class spectrum have the lowest strength per unit of body mass. This was similar when examining Sinclair scores for boys, however, Sinclair scores eliminated all weight class differences for girls. This demonstrates the effectiveness of Sinclair scores to account for weight class differences in OW performance, particularly for girls. However, the Sinclair calculation only takes into consideration the total lifted, while the allometric scaling used in the present study allowed normalization of the individual lifts. Thus, the combination of using allometric scaling and Sinclair scores may provide coaches and competitors a wholistic examination of not only overall OW performance, but performance on the individual lifts.

One previous study examined the influence of normalization via allometric scaling and Sinclair scores on sex-specific differences for IWF senior competitors (4), demonstrating that normalization tended to eliminate the sex differences for snatch, but not clean & jerk or total. Since adult men tend to have greater overall muscle mass than adult women, it is not surprising that men tended to yield superior performance than women after normalization by body weight alone without consideration of muscle mass. Similarly, in the present study, normalization via allometric scaling or Sinclair scores did not eliminate sex-based differences, such that boys remained stronger than girls after normalization. The reason for this is likely multifactorial and cannot be narrowed down to one specific mechanism. One potential reason could be the age range for youth competitors, which spans the growth and development period. To compete in youth competitions, competitors must be between 13-17-years old. Previous research has suggested that much of the growth and development process (i.e., changes in muscle morphology and neuromuscular function) for boys and girls occurs between 10-15-years old (5,13,16,17), which suggests that youth competitors between 13-15-years old are likely undergoing significant morphological and neuromuscular changes, which may act as a confounding factor when examining sex-based differences. Furthermore, younger competitors likely do not have the training age or experience of their senior competitor counterparts, which may introduce sex-based differences in longitudinal adaptations, particularly when considering the growth and development process. Nevertheless, future studies should consider examining the underlying biomechanical and physiological mechanisms that may account for sex-based differences in normalized OW performance, even after accounting for body weight, among youth competitors. Furthermore, future studies should consider examining the differences in OW performance among youth competitors when age is used as an independent variable (i.e., separate competitors by their age). Although age is not considered a factor for competitive performance in youth OW competitions, future studies examining how age impacts OW performance may provide unique information to coaches and practitioners.

In conclusion, the present study provides sex- and weight class-specific percentile rankings for absolute performance for youth OW competitors. Furthermore, the present study also provides percentile rankings for allometrically scaled

performance and Sinclair scores, which may be relevant for coaches and athletes when examining OW performance relative to body weight. Interestingly, when accounting for body weight, whether through allometric scaling or Sinclair scores, the middle weight classes tended to outperform the lightest and heaviest weight classes, while still maintaining greater performance for boys than girls. Thus, the present study provides unique insight with regards to the role that body weight plays when examining weight class differences for youth OW competitors. These data may be valuable for assessing progress of youth OW competitors and when considering appropriate weight classes for these competitors based on their current snatch, clean & jerk, and total results.

CONFLICTS OF INTEREST

The author has no conflicts of interest that are directly relevant to the contents of this manuscript.

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ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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