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

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ABSTRACT

The present study provided percentile rankings and gender and weight class comparisons, for absolute and allometrically scaled Olympic Weightlifting (OW) performance, as well as Sinclair scores, for International Weightlifting Federation (IWF) World Championships competitors. Data from the IWF Senior World Championships for 2018, 2019, 2021, and 2022 were compiled. OW performance was allometrically scaled for body weight, and Sinclair scores were calculated based on IWF standards. Percentile rankings and gender and weight class differences were computed for absolute and allometrically scaled OW performance measures, as well as Sinclair scores. This study provided percentile rank values for absolute, allometrically scaled, and Sinclair scored OW performance with the weight classes implemented in 2018 by the IWF. OW performance increased with weight class. When allometrically scaled, the lightest and heaviest weight classes had the lowest OW performance, while Sinclair scores were similar across weight class. Men remained stronger than women for allometrically scaled clean & jerk and total, which was similar for gender-related comparisons of Sinclair scores, while allometrically scaled snatch was similar for men and women. The present results provide coaches and practitioners percentile rankings and allometric parameters that may be used to assess OW performance for elite-level weightlifting competitors.

Keywords: resistance; weight; gender; performance

INTRODUCTION

Olympic Weightlifting (OW) is a popular international sport that involves the execution of two competition lifts: the snatch and the clean & jerk. While commonly used in sports performance training programs (Stone et al., 2005), OW itself is a competitive sport with national and international competitions, including the Olympic Games. Within the sport of Weightlifting, men and women are separated into 10 unique body weight categories to permit competition against individuals with similar body weight and within the same gender. In competition, competitors for each weight class receive 1st, 2nd, or 3rd place recognition for the most weight lifted during the snatch, clean & jerk, and the combined total of both lifts. Furthermore, OW competitions use a metric called the Sinclair coefficient (International Weightlifting Federation, n.d.-b; Sinclair, 1985), which mathematically accounts for differences in body weight, to determine the best overall lifter independent of body weight. Although competitions

exist across the amateur level of OW, each year the International Weightlifting Federation (IWF) hosts the World Championships to allow the top OW athletes in the world a chance to compete against other athletes of a similar caliber. Thus, OW athletes at the amateur level up to the elite level look to the performance of World Championships competitors to gauge the current level of their OW performance.

One valuable method by which OW coaches and competitors may assess performance is by comparing the athlete's performance to normative, percentile rankings from previous IWF competitors. Although previous studies and texts have provided percentile rankings for OW performance in athletic populations (Haff & Triplett, 2016; Hoffman, 2006), none have done so for athletes competing specifically in the sport of Weightlifting. Since one of the goals of training for OW competitions is to perform in the top percentile of athletes, it seems pertinent to have standards against which these comparisons can be made. However, since the IWF does also take into consideration the influence of body weight on OW performance particularly by using the Sinclair coefficient (International Weightlifting Federation, n.d.-b; Sinclair, 1985), it may be valuable to also understand how normalizing OW performance to body weight may affect the results of competition.

Typically, previous studies have suggested using body weight normalization procedures, namely allometric scaling, to account for the influence of body weight on OW performance (Batterham & George, 1997; Marković & Sekulić, 2006; Stone et al., 2005). The purpose of allometric scaling is to scale a variable by an individual's body weight raised to an exponential power called the allometric parameter. The allometric parameter is specific to the chosen test, allowing researchers the flexibility to scale to specific performance tests. Previous studies in assessing OW performance (Batterham & George, 1997; Marković & Sekulić, 2006; Stone et al., 2005), and other studies examining athletic performance (Jaric et al., 2005; Markovic & Jaric, 2004; Nevill et al., 1992; Nevill & Holder, 1995; Nuzzo, 2015), have advocated for the use of allometric scaling over simple ratio scaling, which involves dividing performance by body weight. The reason for the preference towards allometric scaling is that many performance variables do not exhibit a linear model of best fit between body weight and performance, which is an underlying assumption for ratio scaling (Jaric et al., 2005; Nevill et al., 1992; Nevill & Holder, 1995). Thus, before traditional normalization procedures such as ratio scaling can be used to examine normalized OW performance, it is necessary to determine if allometric scaling is a more appropriate normalization procedure by determining the model of best fit between OW performance and body weight. Furthermore, although the Sinclair coefficient allows a body weight independent comparison of the total weight lifted during an OW competition (International Weightlifting Federation, n.d.-b; Sinclair, 1985), this calculation does not apply to the individual lifts. Therefore, the purpose of this study was twofold. First, the present study aimed to provide percentile rankings and comparisons for absolute OW performance for IWF World Championships competitors based on gender and weight class. Second, the present study aimed to provide percentile rankings and comparisons for allometrically scaled OW performance and Sinclair scores based on gender and weight class.

MATERIALS AND METHODS

Participants

Participants included senior Olympic weightlifters (n = 1,862, n = 972 men, n = 890 women) who participated in the IWF Senior World Championships in 2018, 2019, 2021, and 2022. Men were further divided into the following weight classes: 55 kg (n = 47), 61 kg (n = 94), 67 kg (n = 103), 73 kg (n = 109), 81 kg (n = 123), 89 kg (n = 108), 96 kg (n = 123), 102 kg (n = 77), 109 kg (n = 92), and 109+ kg (n = 96). Women were further divided into the following weight classes: 45 kg (n = 45), 49 kg (n = 96), 55 kg (n = 118), 59 kg (n = 133), 64 kg (n = 118), 71 kg (n = 110), 76 kg (n = 67), 81 kg (n = 68), 87 kg (n = 63), 87+ kg (n = 72). The Mississippi State University Institutional Review Board (IRB) determined the data were considered exempt (official letter from the IRB, November 28th, 2022) since the data are publicly accessible (International Weightlifting Federation, n.d.-a).

Research Design

The present study analyzed OW performance data for the International Weightlifting Federation (IWF) Senior World Championships in 2018, 2019, 2021, and 2022. Due to the COVID-19 pandemic, there were no available data for 2020. Since the IWF changed the competitive weight classes after the 2017 and prior to the 2018 world championships, only data using the updated weight classes (2018 and onward) were used herein. These data were used to determine 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. Additionally, percentile rank scores were calculated for the Sinclair score results. Data were examined for men and women, as well as for each weight class within men and women. Therefore, the independent variables in the present study were gender and weight class, while the dependent variables were weight lifted for the snatch (absolute and allometrically scaled), clean & jerk (absolute and allometrically scaled), and total weight lifted (absolute, allometrically scaled, and Sinclair score).

Procedures

Data from the IWF Senior World Championships for 2018, 2019, 2021, and 2022 were compiled from competition results publicly available on the IWF website (International Weightlifting Federation, n.d.-a). The best snatch, clean & jerk, and totals were taken for lifters who completed at least one valid snatch and one successful clean & jerk. Athletes were only included if they achieved a successful total (kg) in competition, with the total being the sum of the best snatch weight (kg) and best clean & jerk weight (kg) if there was at least one valid attempt for each lift. Athletes who did not achieve at least one valid snatch and one valid clean & jerk attempt were excluded.

Statistical Analyses

Descriptive statistics (mean, standard deviation, and percentile rankings) were computed for all absolute and allometrically scaled performance measures, as well as Sinclair scores. These percentile rankings were used to generate reference values for absolute and allometrically scaled snatch, clean & jerk, and total lifts, as well as Sinclair scores for by gender and weight class. Although the specific weight class cutoffs are different for men and women, both men and women had 10 competitive weight classes each. Since these weight class designations are designed to account for gender-related differences in body weight and performance, gender x weight class comparisons were performed to allow comparisons from lightest to heaviest weight classes within and across gender. For men's weight classes: 1 = 55 kg, 2 = 61 kg, 3 = 67 kg, 4 = 73 kg, 5 = 81 kg, 6 = 89 kg, 7 = 96 kg, 8 = 102 kg, 9 = 109 kg, 10 = 109+ kg. For women's weight classes: 1 = 45 kg, 2 = 49 kg, 3 = 55 kg, 4 = 59 kg, 5 = 64 kg, 6 = 71 kg, 7 = 76 kg, 8 = 81 kg, 9 = 87 kg, 10 = 87+ kg. Two-way analyses of variance (ANOVAs) (gender [men vs. women] 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 were used to test for any gender or weight class differences for OW performance measures.

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 R2 change in SPSS) were determined using the *F*-test described by Pedhazur (Pedhazur, 1997). For men, the model of best fit for the relationship between body weight and absolute performance measures were as follows: snatch – quadratic ($r^2 = 0.616$, $p < 0.001$), clean & jerk – quadratic ($r^2 = 0.677$, $p < 0.001$), total – quadratic ($r^2 = 0.665$, $p < 0.001$). For women, the model of best fit for the relationship between body weight and absolute performance measures were as follows: snatch – quadratic ($r^2 = 0.534$, $p < 0.001$), clean & jerk – cubic ($r^2 = 0.562$, $p = 0.002$), total – cubic ($r^2 = 0.563$, $p = 0.008$). Therefore, all absolute performance metrics were normalized via allometric scaling in lieu 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 (Jaric et al., 2005; Weir et al., 1999). 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 (Jaric et al., 2005; Weir et al., 1999). 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 (International Weightlifting Federation, n.d.-b).

Since allometric scaling and the Sinclair equation normalize performance metrics to body weight

(Jaric et al., 2005; Sinclair, 1985; Weir et al., 1999), there should be at least a decrease in the magnitude of relationship between body weight and performance, if not a statistical change, if allometric scaling is appropriate. Therefore, Pearson product moment correlation coefficients were calculated for the relationship between body weight and absolute performance measures and body weight and allometrically scaled performance measures. The following qualitative evaluations of the strength of association were made according to Mukaka (2012) 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 (Preacher, 2002). 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 were performed using partial η^2 such that an effect size of ≥ 0.14 was considered a large effect, an effect size of ≥ 0.06 and < 0.14 was considered a moderate effect, and an effect size of ≥ 0.01 and < 0.06 was considered a small effect, and an effect size of < 0.01 was considered a negligible effect, as well as Cohen's *d* such that an effect size ≥ 0.80 was considered a large effect, an effect size ≥ 0.50 and < 0.80 was considered a moderate effect, an effect size ≥ 0.20 and < 0.50 was considered a small effect, and an effect size < 0.20 was considered a negligible effect.

RESULTS

Means, standard deviations, and percentile rankings for absolute and allometrically scaled measures, as well as Sinclair scores, can be found in Tables 1-7 and Figures 1-4, while calculated allometric parameters (*b*) can be found in Table 8.

For the men, body weight exhibited high, significant positive correlations with absolute performance measures ($r \geq 0.759$, $p < 0.001$), negligible, significant negative correlations with allometrically scaled performance measures ($r \leq -0.259$, $p < 0.001$), and a negligible, significant positive correlation with Sinclair scores ($r = 0.122$, $p < 0.001$). The correlation coefficients for the relationships between body weight and all performance measures significantly decreased with allometric scaling and Sinclair calculations ($|z\text{-score}| \geq 20.481$, $p < 0.001$).

For the women, body weight exhibited high, significant positive correlations with absolute performance measures ($r \geq 0.706$, $p < 0.001$), negligible, non-significant negative correlations with allometrically scaled performance measures ($r \leq -0.039$, $p \geq 0.248$), and a negligible, non-significant negative correlation with Sinclair scores ($r = -0.048$, $p = 0.149$). The correlation coefficients for the relationships between body weight and all performance measures significantly decreased with allometric scaling and Sinclair calculations ($|z\text{-score}| \geq 19.336$, $p < 0.001$).

There was a significant gender x weight class interaction for absolute snatch ($p < 0.001$, $\eta^2 = 0.083$). The men were stronger than the women across all weight classes ($p < 0.001$, $d \geq 3.801$). Within the men, 55 < 61 < 67 < 73, 81 < 89, 96 < 102 < 109 < 109+ ($p \leq 0.027$, $d \geq 0.457$; note: 96 = 102, $p = 1.000$, $d = 0.256$). Within the women, 45 < 49 < 55 < 59, 64 < 71, 76, 81, 87 < 87+ ($p \leq 0.046$, $d \geq 0.571$; note: 64 = 71, $p = 1.000$, $d = 0.294$; 71 < 81, $p = 0.012$, $d = 0.688$).

There was a significant gender x weight class interaction for allometrically scaled snatch ($p < 0.001$, $\eta^2 = 0.017$). For the following gender comparisons of weight class, use the following classifications: for men's weight classes: 1 = 55 kg, 2 = 61 kg, 3 = 67 kg, 4 = 73 kg, 5 = 81 kg, 6 = 89 kg, 7 = 96 kg, 8 = 102 kg, 9 = 109 kg, 10 = 109+ kg; for women's weight classes: 1 = 45 kg, 2 = 49 kg, 3 = 55 kg, 4 = 59 kg, 5 = 64 kg, 6 = 71 kg, 7 = 76 kg, 8 = 81 kg, 9 = 87 kg, 10 = 87+ kg. There were no differences for weight classes 1, 2, and 4 – 9 ($p \geq 0.080$, $d \leq 0.364$), while the men were stronger than the women for weight class 3 ($p = 0.011$, $d = 0.350$) and the women were stronger than the men for weight class 10 ($p = 0.002$, $d = 0.452$). Within the men, 55 < 67, 73, 81, 89, 96 ($p \leq 0.007$, $d \geq 0.672$), 109+ < 61, 67, 73, 81, 89, 96, 102, 109 ($p < 0.001$, $d \geq 1.097$), and 109 < 73 ($p = 0.050$, $d = 0.509$). Within the women, 45 < 49, 55, 59, 64, 71, 76, 81, 87 ($p \leq 0.031$, $d \geq 0.686$), 49 < 59, 64, 76 ($p \leq 0.038$, $d \geq 0.418$), and 87+ < 59, 64, 71, 76, 81 ($p \leq 0.002$, $d \geq 0.531$).

There was a significant gender x weight class interaction for absolute clean & jerk ($p < 0.001$, $\eta^2 = 0.071$). The men were stronger than the women across all weight classes ($p < 0.001$, $d \geq 3.883$). Within the men, 55 < 61 < 67 < 73, 81 < 89, 96 < 102, 109 < 109+ ($p \leq 0.003$, $d \geq 0.592$; note: 96 = 102, $p = 1.000$, $d = 0.240$). Within the women, 45 < 49, 55 < 59, 64 < 71 < 76, 81, 87 < 87+ ($p \leq 0.016$, $d \geq 0.523$; note: 64 = 71, $p = 1.000$, $d = 0.287$).

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

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	111.00	92.00	107.25	113.40	117.50	114.00	135.00	132.00	130.00	140.00	150.95
10	118.00	102.60	110.50	117.00	124.00	122.20	139.00	140.00	144.00	145.00	157.40
15	123.00	104.00	115.00	120.00	130.00	127.60	140.35	143.60	149.40	150.00	163.00
20	130.00	104.60	116.00	123.00	134.00	133.00	144.60	146.00	150.00	155.00	165.40
25	135.00	105.00	117.00	126.00	135.00	138.00	146.25	150.00	154.50	157.25	170.00
30	137.00	106.40	117.50	128.00	136.00	141.20	150.00	153.00	156.80	160.90	171.10
35	140.00	108.00	120.00	130.00	137.00	145.00	152.00	155.00	158.60	165.00	173.00
40	144.20	108.20	120.00	132.00	138.00	145.00	154.60	155.60	160.00	165.20	175.80
45	147.00	109.60	121.75	134.00	141.00	147.00	155.05	158.00	162.10	169.85	176.00
50	150.00	110.00	123.00	135.00	143.00	148.00	157.00	160.00	164.00	170.00	180.00
55	153.00	111.00	124.00	136.00	145.00	150.00	158.00	160.20	165.90	173.00	180.35
60	155.80	112.80	125.00	137.00	145.00	151.40	160.00	163.00	167.00	174.00	183.20
65	160.00	114.20	125.00	138.00	147.00	154.00	160.00	164.00	168.00	175.00	187.00
70	162.00	115.00	127.50	140.00	150.00	155.00	162.00	165.00	170.00	175.10	190.00
75	165.00	117.00	130.00	140.00	151.00	157.00	164.75	168.00	172.00	177.75	192.00
80	168.40	117.40	132.00	142.00	153.00	159.00	165.20	170.00	174.40	180.00	197.00
85	173.00	118.00	135.00	143.00	153.00	162.00	166.65	172.40	175.30	182.05	200.45
90	176.00	120.00	135.00	145.60	154.00	164.00	168.00	175.60	177.00	188.70	205.30
95	185.00	120.00	139.25	149.60	156.00	168.00	169.55	180.00	180.00	195.35	215.00
Mean	149.23	109.57*	122.72*[1]	132.69*[1,2]	141.14*[1-3]	145.51*[1-3]	154.82*[1-5]	158.23*[1-5]	161.78*[1-6]	168.33*[1-8]	180.10*[1-9]
SD	23.13	10.78	10.59	11.16	12.26	17.47	11.56	14.24	13.46	15.15	19.58
n	972	47	94	103	109	123	108	123	77	92	96

Percentile	All	45	49	55	59	64	71	76	81	87	87+
5	68.00	56.30	65.00	65.95	70.00	73.90	77.55	75.80	83.00	81.40	81.65
10	73.00	59.20	66.70	71.90	73.40	79.00	83.10	87.40	84.90	88.40	95.30
15	76.00	62.70	70.00	74.85	79.10	81.85	85.00	91.00	93.00	90.00	99.90
20	79.00	64.20	71.00	76.80	81.60	83.80	87.00	92.00	95.00	92.00	102.00
25	82.00	65.00	72.00	78.00	82.00	85.75	88.00	93.00	96.50	93.00	105.00
30	83.00	67.00	73.00	80.00	84.00	87.70	89.00	94.00	98.00	95.00	105.90
35	85.00	68.00	73.95	80.00	85.00	89.00	90.00	95.00	98.15	97.40	108.00
40	88.00	68.40	75.00	82.00	86.00	90.00	90.00	96.00	100.00	98.60	110.00
45	89.95	69.70	75.65	82.00	88.00	91.00	92.00	98.00	101.00	100.00	113.70
50	91.00	70.00	78.00	83.00	89.00	92.00	93.00	100.00	102.00	100.00	115.00
55	93.00	70.00	78.00	84.00	90.00	93.00	94.00	101.00	103.00	101.20	116.00
60	94.00	70.00	78.20	85.00	90.00	93.00	95.00	103.60	105.00	103.40	118.60
65	96.00	71.00	80.00	85.35	91.00	95.00	98.15	105.00	105.00	105.00	120.00
70	98.00	73.20	81.00	87.00	92.80	96.00	100.00	105.60	106.00	107.00	121.00
75	101.00	74.50	82.75	88.00	94.50	97.00	102.00	107.00	108.00	108.00	122.00
80	103.00	75.80	83.00	90.00	96.00	99.00	103.00	108.00	108.20	109.00	124.40
85	106.00	76.00	86.00	91.15	96.90	101.00	105.35	110.00	110.65	110.40	128.05
90	110.00	77.00	88.30	93.00	100.60	105.00	110.00	112.20	113.10	112.60	130.70
95	116.00	77.70	92.15	97.05	103.00	109.05	112.00	118.00	117.55	115.80	141.70
Mean	91.24	69.18	77.08[1]	82.72[1,2]	87.84[1-3]	91.47[1-3]	94.42[1-4]	99.58[1-5]	101.35[1-6]	100.44[1-5]	113.51[1-9]
SD	14.71	6.33	8.13	8.60	9.31	9.92	10.16	10.74	10.00	9.58	15.18
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	10.55	10.13	11.34	11.32	11.20	10.18	11.42	10.71	10.44	10.58	9.73
10	11.18	11.28	11.49	11.60	11.66	10.99	11.83	11.33	11.30	10.96	10.00
15	11.51	11.42	11.92	11.90	12.25	11.45	11.94	11.67	11.77	11.31	10.21
20	11.81	11.50	12.03	12.12	12.61	11.90	12.18	11.88	11.85	11.77	10.48
25	12.01	11.56	12.14	12.42	12.69	12.25	12.42	12.31	12.11	11.94	10.63
30	12.22	11.70	12.23	12.64	12.86	12.63	12.68	12.52	12.28	12.23	10.78
35	12.45	11.87	12.45	12.83	12.95	12.86	12.82	12.62	12.45	12.44	11.15
40	12.63	11.96	12.50	13.09	13.17	12.95	13.03	12.73	12.56	12.58	11.30
45	12.79	12.03	12.64	13.22	13.28	13.04	13.17	12.84	12.72	12.80	11.48
50	12.90	12.09	12.75	13.31	13.45	13.16	13.33	12.94	12.88	12.87	11.56
55	13.05	12.18	12.87	13.41	13.62	13.30	13.41	13.06	13.05	13.04	11.69
60	13.19	12.39	12.96	13.52	13.67	13.44	13.50	13.20	13.10	13.12	11.90
65	13.33	12.56	13.05	13.60	13.87	13.67	13.61	13.32	13.20	13.19	12.01
70	13.48	12.67	13.27	13.79	14.11	13.78	13.74	13.42	13.39	13.29	12.20
75	13.64	12.85	13.51	13.84	14.24	13.95	13.91	13.59	13.49	13.40	12.39
80	13.82	12.92	13.70	13.98	14.37	14.14	14.00	13.75	13.67	13.57	12.54
85	14.01	12.96	14.00	14.08	14.39	14.38	14.07	13.96	13.85	13.73	12.74
90	14.23	13.17	14.05	14.36	14.49	14.57	14.25	14.34	13.94	14.21	12.97
95	14.52	13.20	14.45	14.74	14.66	14.92	14.35	14.60	14.08	14.72	13.28
Mean	12.77	12.05	12.76[10]	[1]3.10*[1,10]	13.30[1,10]	12.96[1,10]	13.11[1,10]	12.86[1,10]	12.71[10]	12.73[10]	11.49
SD	1.25	1.18	1.07	1.08	1.12	1.51	0.96	1.14	1.05	1.12	1.14
n	972	47	94	103	109	123	108	123	77	92	96

Percentile	All	45	49	55	59	64	71	76	81	87	87+
5	10.33	9.46	10.52	10.13	10.38	10.54	10.73	10.07	10.69	10.14	9.03
10	10.93	9.94	10.78	11.00	10.98	11.33	11.39	11.71	11.10	11.09	10.10
15	11.37	10.53	11.29	11.44	11.78	11.66	11.58	12.01	12.09	11.15	10.68
20	11.69	10.81	11.46	11.74	12.09	11.96	11.97	12.24	12.15	11.37	10.94
25	11.91	10.92	11.66	11.94	12.19	12.27	12.10	12.33	12.51	11.52	11.27
30	12.11	11.25	11.81	12.22	12.43	12.49	12.21	12.46	12.55	11.81	11.39
35	12.26	11.41	11.93	12.27	12.68	12.68	12.28	12.54	12.74	12.09	11.59
40	12.44	11.62	12.09	12.54	12.83	12.86	12.33	12.78	12.86	12.25	11.81
45	12.58	11.75	12.23	12.57	13.02	13.01	12.52	12.92	13.02	12.38	12.00
50	12.75	11.77	12.57	12.71	13.18	13.12	12.70	13.18	13.12	12.56	12.08
55	12.92	11.80	12.62	12.89	13.31	13.24	12.89	13.32	13.17	12.63	12.19
60	13.10	11.90	12.74	13.01	13.35	13.38	13.00	13.65	13.39	12.81	12.43
65	13.30	11.96	12.91	13.13	13.48	13.56	13.36	13.81	13.52	13.16	12.50
70	13.43	12.30	13.10	13.36	13.75	13.70	13.66	14.05	13.69	13.29	12.57
75	13.63	12.53	13.36	13.51	13.97	13.87	13.85	14.08	13.83	13.44	13.06
80	13.85	12.72	13.42	13.77	14.19	14.08	14.02	14.23	14.03	13.51	13.40
85	14.12	12.76	13.87	13.94	14.35	14.38	14.34	14.45	14.15	13.70	13.58
90	14.39	12.92	14.24	14.23	14.88	14.95	14.97	14.79	14.55	13.90	14.34
95	15.07	13.09	14.87	14.85	15.25	15.62	15.39	15.61	15.07	14.28	15.12
Mean	12.73	11.64	12.46[1]	12.68[1]	13.02[1,2,10]	13.06[1,2,10]	12.89[1,10]	13.15[1,2,10]	13.03[1,10]	12.47[1]	12.11*
SD	1.40	1.07	1.31	1.31	1.37	1.42	1.36	1.39	1.26	1.19	1.57
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

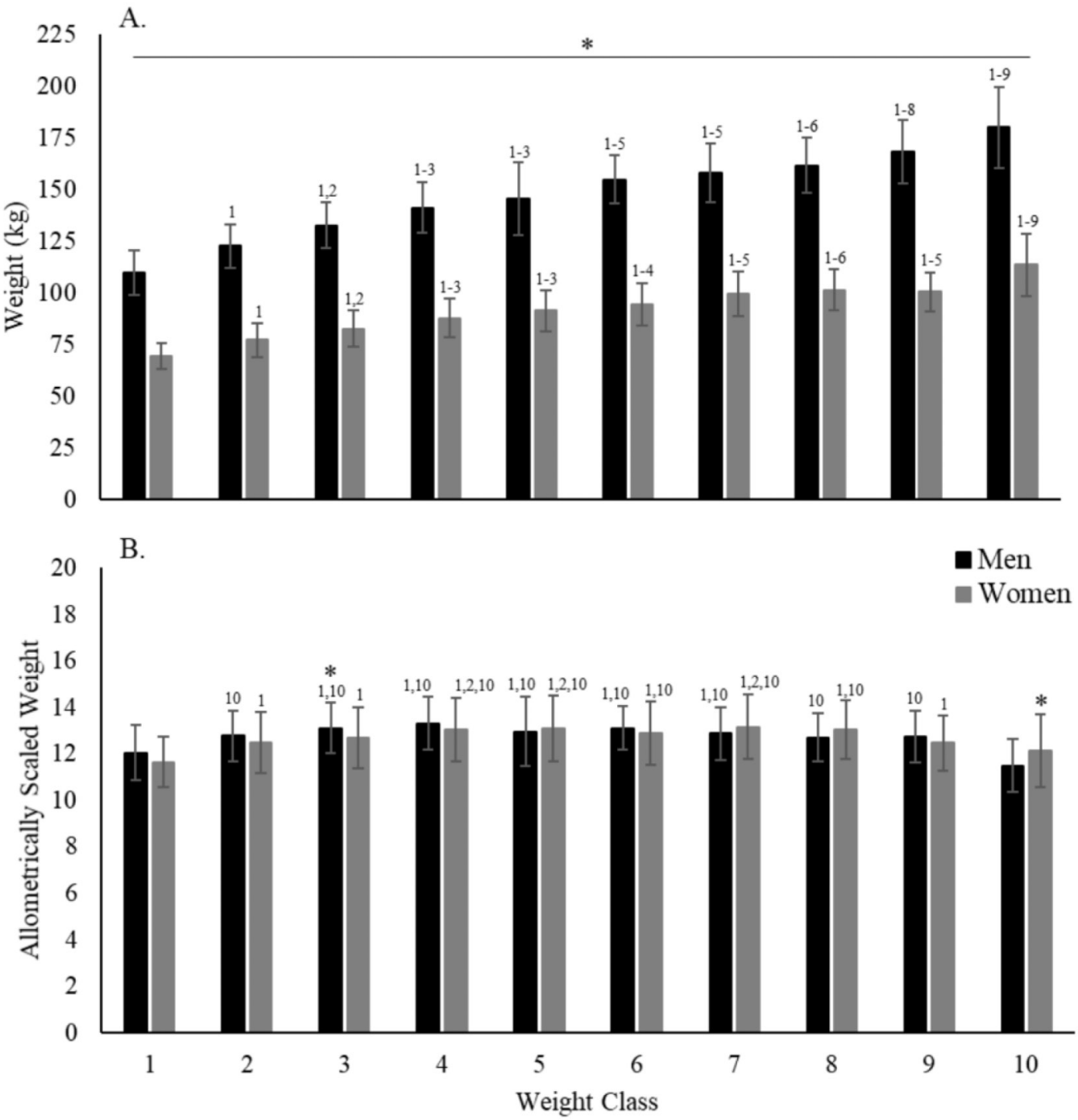

Figure 1. Means and standard deviations for A) absolute and B) allometrically scaled snatch for men and women by weight class. *Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	138.65	120.00	135.75	137.20	146.00	136.80	165.00	166.20	170.90	178.95	190.00
10	146.00	124.60	141.00	145.40	156.00	150.40	170.00	175.00	178.40	182.00	194.00
15	154.00	125.00	143.00	151.20	160.00	160.60	175.35	177.20	182.10	184.95	200.00
20	160.00	127.00	144.00	155.00	162.00	166.80	180.00	182.60	185.00	189.20	205.00
25	165.00	130.00	145.00	158.00	165.00	171.00	183.00	185.00	189.50	193.25	210.00
30	170.00	131.00	148.00	160.00	167.00	174.20	184.70	187.00	190.00	195.00	215.00
35	174.00	132.00	150.00	160.40	169.00	176.00	185.00	189.40	193.00	197.65	218.00
40	177.20	134.20	150.00	162.60	170.00	178.00	187.20	191.00	195.00	201.00	220.00
45	180.00	135.00	151.00	164.00	171.00	180.00	190.00	192.80	198.00	205.00	222.65
50	184.50	138.00	152.50	165.00	174.00	181.00	190.00	195.00	200.00	208.00	225.00
55	187.00	139.00	153.25	165.00	177.00	183.00	194.90	197.40	201.90	210.00	226.35
60	190.00	139.80	155.00	167.00	179.00	185.00	195.00	200.00	205.00	210.00	227.00
65	195.00	141.00	155.00	170.00	180.00	187.00	195.85	201.00	206.00	211.00	230.00
70	197.00	142.00	156.50	171.00	181.00	189.80	198.30	203.80	208.00	215.00	231.00
75	201.00	143.00	158.00	173.00	182.50	191.00	200.00	206.00	212.00	218.00	235.00
80	205.40	144.40	160.00	175.00	184.00	194.20	200.20	208.20	214.00	220.00	239.20
85	210.05	145.00	163.00	176.00	186.00	196.00	203.00	211.00	216.30	221.05	242.00
90	218.00	147.20	165.50	179.60	187.00	198.60	205.00	213.00	217.00	224.40	246.00
95	227.00	156.80	169.75	182.00	192.50	202.00	207.55	220.20	218.10	229.35	250.15
Mean	183.15	135.91*	151.95*1	163.71*1,2	172.71*1-3	177.94*1-3	189.56*1-5	194.34*1-5	198.25*1-6	205.00*1-7	221.63*1-9
SD	27.17	12.71	11.71	12.75	13.82	20.15	13.25	16.52	16.00	16.01	20.83
n	972	47	94	103	109	123	108	123	77	92	96

Percentile	All	45	49	55	59	64	71	76	81	87	87+
5	85.00	72.50	83.85	82.85	85.00	90.00	95.00	95.00	101.45	105.00	106.65
10	90.00	77.20	85.70	88.90	92.00	99.00	99.10	108.00	112.30	110.40	123.60
15	95.00	79.00	87.55	90.00	100.00	101.85	103.65	115.00	115.00	113.80	126.95
20	98.00	80.00	90.00	95.00	101.80	104.00	107.00	115.00	116.80	115.00	130.00
25	101.00	80.50	91.25	96.75	104.00	105.75	108.00	117.00	119.00	117.00	134.25
30	104.00	81.00	93.00	98.00	105.00	108.00	110.00	118.40	120.00	118.20	136.00
35	105.00	83.10	93.00	100.00	105.00	108.65	111.85	120.00	122.00	120.00	140.00
40	108.00	85.00	94.00	101.60	106.00	110.00	114.00	120.20	123.00	121.60	141.20
45	110.00	86.00	95.00	103.00	108.00	112.00	115.00	122.00	125.05	123.00	142.85
50	113.00	86.00	96.00	104.00	109.00	113.50	116.00	123.00	127.00	125.00	145.00
55	115.00	87.00	97.00	105.00	110.00	115.00	118.00	124.40	127.95	126.40	146.00
60	117.00	87.00	98.00	106.00	113.00	116.00	119.60	128.80	130.40	128.40	150.00
65	120.00	89.70	100.00	107.35	115.00	117.35	120.15	130.00	133.00	130.00	152.00
70	122.00	91.00	101.00	109.00	116.00	120.00	123.70	131.60	134.30	130.00	154.10
75	125.00	91.00	101.75	110.00	118.00	121.00	125.00	134.00	135.75	135.00	155.00
80	128.80	92.80	102.60	111.00	119.20	123.00	127.00	136.00	136.20	138.40	157.80
85	133.00	95.00	104.45	113.00	122.00	124.00	130.35	137.80	137.00	140.40	160.10
90	138.00	95.00	109.30	114.20	126.00	126.10	133.90	142.80	139.20	143.60	168.50
95	147.45	101.40	114.15	120.05	131.30	132.10	137.90	151.20	145.30	151.80	180.10
Mean	113.74	86.27	96.53[1]	102.65[1]	109.74[1-3]	112.80[1-3]	116.42[1-4]	124.42[1-6]	126.10[1-6]	125.86[1-6]	144.69[1-9]
SD	18.90	7.58	9.28	10.99	12.46	12.11	13.09	14.27	12.60	13.34	18.74
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	14.45	14.24	15.21	14.82	15.15	13.20	15.16	14.69	14.65	14.73	13.34
10	15.05	14.74	15.83	15.55	15.90	14.79	15.68	15.42	15.29	15.04	13.92
15	15.50	14.80	16.02	16.18	16.35	15.61	16.27	15.81	15.73	15.31	14.31
20	15.86	15.05	16.23	16.60	16.61	16.10	16.64	16.18	15.84	15.57	14.54
25	16.18	15.51	16.29	16.85	16.87	16.56	16.79	16.40	16.18	15.91	14.74
30	16.39	15.54	16.64	17.05	17.01	16.85	16.93	16.60	16.23	16.05	14.85
35	16.67	15.63	16.80	17.16	17.23	16.98	17.04	16.76	16.48	16.31	15.11
40	16.85	15.88	16.92	17.38	17.32	17.26	17.20	16.99	16.63	16.69	15.31
45	17.01	15.98	16.97	17.50	17.49	17.34	17.43	17.12	16.86	17.01	15.46
50	17.16	16.35	17.10	17.60	17.71	17.43	17.54	17.22	17.03	17.12	15.60
55	17.33	16.45	17.20	17.67	18.03	17.64	17.86	17.39	17.22	17.28	15.73
60	17.48	16.56	17.36	17.79	18.23	17.89	17.93	17.62	17.47	17.30	15.89
65	17.67	16.70	17.39	18.10	18.33	18.05	18.04	17.68	17.62	17.46	16.05
70	17.91	16.83	17.56	18.23	18.44	18.31	18.24	18.03	17.83	17.71	16.24
75	18.12	16.95	17.71	18.44	18.62	18.43	18.34	18.20	18.07	18.01	16.46
80	18.33	17.09	17.93	18.64	18.76	18.70	18.45	18.41	18.31	18.08	16.68
85	18.54	17.21	18.30	18.78	18.97	18.88	18.68	18.68	18.52	18.19	16.79
90	18.80	17.42	18.55	19.15	19.05	19.15	18.82	18.78	18.59	18.46	17.02
95	19.17	18.56	19.02	19.41	19.66	19.51	19.00	19.38	18.90	18.87	17.20
Mean	17.03	16.10*	17.06*[1,10]	17.49*[1,10]	17.64*[1,9,10]	17.20*[1,10]	17.45*[1,10]	17.20*[1,10]	16.97*[10]	16.92*[10]	15.52*
SD	1.52	1.49	1.27	1.33	1.36	1.89	1.18	1.43	1.37	1.30	1.23
n	972	47	94	103	109	123	108	123	77	92	96

Percentile	All	45	49	55	59	64	71	76	81	87	87+
5	12.04	11.46	12.70	11.97	11.95	12.02	12.08	11.76	12.34	12.06	11.06
10	12.74	12.19	13.00	12.73	12.76	13.20	12.70	13.49	13.37	12.77	12.17
15	13.25	12.47	13.26	12.92	13.88	13.62	13.29	14.09	13.76	13.06	12.55
20	13.63	12.63	13.66	13.64	14.12	13.84	13.67	14.26	14.00	13.31	13.06
25	13.83	12.72	13.80	13.90	14.41	14.06	13.80	14.35	14.25	13.47	13.47
30	14.07	12.82	14.09	14.07	14.53	14.39	14.00	14.58	14.42	13.71	13.60
35	14.30	13.12	14.14	14.39	14.66	14.50	14.16	14.73	14.54	13.78	13.63
40	14.46	13.49	14.31	14.62	14.72	14.66	14.51	14.97	14.88	13.95	13.74
45	14.66	13.58	14.40	14.81	14.95	14.92	14.70	15.03	14.98	14.14	13.94
50	14.83	13.72	14.54	14.93	15.10	15.15	14.87	15.10	15.10	14.37	14.08
55	15.00	13.76	14.69	15.04	15.29	15.35	15.07	15.35	15.30	14.70	14.30
60	15.17	13.81	14.89	15.17	15.67	15.51	15.20	15.91	15.81	14.79	14.44
65	15.38	14.16	15.14	15.41	15.91	15.69	15.48	15.98	15.89	15.03	14.84
70	15.70	14.35	15.29	15.61	16.06	15.99	15.72	16.13	16.02	15.25	15.01
75	15.90	14.37	15.44	15.75	16.33	16.13	15.87	16.44	16.16	15.59	15.24
80	16.10	14.63	15.66	15.89	16.56	16.37	16.13	16.67	16.27	15.88	15.56
85	16.38	15.03	15.88	16.22	16.94	16.50	16.64	16.86	16.42	16.20	15.97
90	16.87	15.07	16.62	16.39	17.46	16.88	16.96	17.51	16.61	16.55	16.54
95	17.58	16.04	17.28	17.19	18.22	17.66	17.51	18.53	17.44	17.44	18.09
Mean	14.82	13.65	14.65[1]	14.74[1]	15.22[1,10]	15.05[1,10]	14.83[1]	15.32[1,10]	15.10[1]	14.53	14.28
SD	1.64	1.20	1.40	1.57	1.71	1.62	1.64	1.72	1.48	1.55	1.80
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

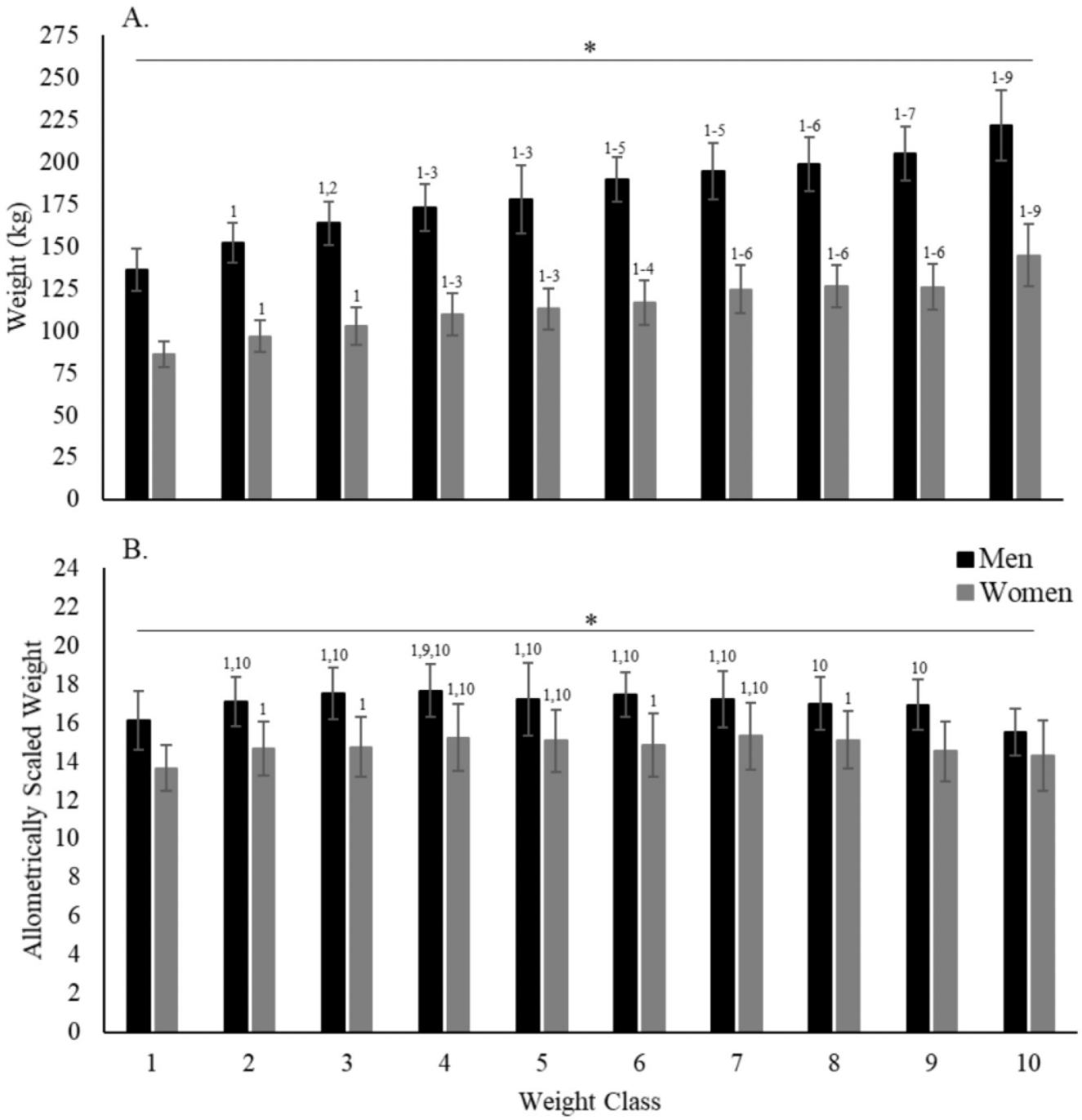

Figure 2. Means and standard deviations for A) absolute and B) allometrically scaled clean & jerk for men and women by weight class. *Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	251.00	214.00	244.50	253.20	264.00	250.20	298.25	297.20	300.90	322.00	344.55
10	265.00	223.80	253.00	261.20	281.00	274.00	310.90	314.60	326.60	328.80	354.50
15	277.00	235.00	258.00	271.60	290.00	288.60	320.00	324.20	332.10	335.95	365.10
20	289.60	235.60	260.00	279.80	298.00	299.80	326.00	330.00	337.60	345.00	370.00
25	298.00	236.00	261.75	286.00	300.50	312.00	330.00	337.00	340.00	349.25	376.25
30	307.00	238.40	266.00	290.00	303.00	317.00	334.10	340.20	346.00	355.90	383.30
35	315.00	240.60	271.00	291.40	305.00	320.00	337.00	343.40	350.30	362.75	390.00
40	322.00	242.20	272.00	295.00	309.00	323.20	341.20	347.00	357.00	370.00	396.00
45	328.00	243.60	274.00	297.00	311.50	326.80	345.00	351.00	361.20	373.85	400.00
50	335.00	248.00	276.00	300.00	319.00	330.00	350.00	353.00	365.00	379.50	402.50
55	340.00	249.40	277.00	302.20	322.00	332.00	352.00	357.20	368.90	383.15	407.70
60	346.00	250.80	279.00	306.00	325.00	336.00	353.00	361.80	372.80	385.80	412.20
65	352.00	253.20	280.75	307.60	327.50	341.20	356.70	365.60	375.70	388.00	418.10
70	360.00	257.20	283.00	310.00	331.00	344.80	361.00	369.80	377.60	389.00	421.90
75	367.00	260.00	286.25	312.00	333.00	348.00	362.75	374.00	382.50	391.75	426.50
80	374.00	260.00	292.00	315.00	336.00	351.00	365.00	378.00	388.00	394.40	432.00
85	383.00	262.80	293.00	317.40	337.50	357.00	369.65	380.80	390.30	400.10	436.45
90	393.00	265.00	299.00	322.60	342.00	363.00	371.00	389.20	393.00	415.40	449.30
95	413.35	275.60	308.50	327.40	347.00	372.00	374.55	396.40	396.10	422.75	462.60
Mean	332.38	245.49*	274.6[7*1]	296.40[*1,2]	313.84[*1-3]	323.46[*1-3]	344.38[*1-5]	352.57[*1-5]	360.03[*1-6]	373.33[*1-8]	401.73[*1-9]
SD	49.77	22.62	21.47	22.96	25.54	37.21	23.64	29.77	28.67	29.68	39.28
n	972	47	94	103	109	123	108	123	77	92	96
Percentile	**All**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**87**	**87+**
5	153.00	127.40	149.70	147.85	154.70	165.80	174.55	170.80	184.45	187.00	192.20
10	163.00	136.00	152.70	160.00	164.40	177.90	182.20	199.00	199.90	198.40	220.20
15	170.00	141.90	157.55	166.70	180.00	184.85	189.65	203.80	209.70	206.00	228.90
20	177.00	144.20	163.00	170.80	183.80	187.00	192.40	209.60	213.00	209.60	233.40
25	183.00	146.50	164.25	173.00	186.50	192.75	197.75	211.00	218.25	211.00	238.25
30	187.00	149.60	166.00	178.00	188.00	196.00	202.00	213.00	220.70	214.20	242.70
35	191.00	151.20	166.95	181.65	191.00	198.00	203.00	213.80	222.15	216.00	248.00
40	196.00	153.40	170.00	184.00	193.60	200.00	204.00	216.20	223.00	220.00	251.80
45	200.00	155.00	172.00	185.00	196.30	203.00	205.95	220.00	225.05	221.80	256.85
50	203.00	156.00	173.50	186.50	199.00	206.00	208.00	223.00	226.00	224.00	258.50
55	207.00	157.00	175.35	190.00	201.00	208.00	211.00	225.80	230.00	230.00	264.15
60	211.00	157.60	176.40	191.40	202.40	209.40	214.20	229.80	234.80	233.00	266.80
65	215.00	160.70	178.05	194.00	205.00	213.00	218.15	235.20	237.85	234.60	269.25
70	221.00	163.20	180.90	195.30	206.80	215.00	224.00	238.60	239.60	239.60	275.00
75	225.00	164.50	182.75	198.00	212.00	218.00	228.00	242.00	242.75	244.00	279.50
80	231.00	168.60	187.00	200.00	215.00	221.00	231.00	243.40	245.00	249.00	283.20
85	239.00	170.00	189.35	203.00	217.90	223.15	234.35	245.00	247.00	250.00	286.05
90	247.00	171.40	195.20	209.10	225.60	232.00	241.90	256.60	253.30	253.20	300.60
95	262.45	179.70	206.00	213.05	231.30	238.05	250.90	269.60	261.10	267.00	321.15
Mean	204.98	155.44	173.61[1]	185.37[1,2]	197.59[1-3]	204.26[1-3]	210.84[1-4]	224.00[1-4]	227.46[1-6]	226.30[1-6]	258.21[1-9]
SD	33.26	13.45	17.01	19.18	21.27	21.55	22.68	24.62	21.84	22.35	33.45
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	25.10	24.55	26.53	26.27	26.28	23.43	26.78	25.29	25.19	25.58	22.46
10	26.41	25.67	27.57	27.25	27.67	25.59	27.55	26.80	26.82	26.08	24.07
15	27.06	26.88	27.94	28.01	28.71	26.93	28.49	27.68	27.50	26.70	24.59
20	27.69	26.97	28.18	28.93	29.32	28.03	28.94	28.44	27.83	27.29	24.92
25	28.17	27.04	28.37	29.45	29.57	29.01	29.20	28.81	28.01	27.73	25.20
30	28.69	27.38	28.90	29.84	29.92	29.50	29.60	29.08	28.43	28.17	25.99
35	29.19	27.57	29.32	30.11	29.96	29.72	29.76	29.44	28.87	29.09	26.39
40	29.51	27.76	29.52	30.43	30.42	30.13	30.28	29.82	29.27	29.41	26.60
45	29.82	27.92	29.65	30.59	30.69	30.35	30.64	29.94	29.59	29.93	26.73
50	30.03	28.41	29.90	30.91	31.36	30.72	30.91	30.07	30.07	30.11	27.14
55	30.37	28.58	30.02	31.07	31.62	30.89	31.14	30.34	30.23	30.44	27.47
60	30.59	28.72	30.23	31.55	31.99	31.34	31.35	30.75	30.64	30.51	27.73
65	30.91	29.01	30.50	31.66	32.20	31.75	31.62	31.05	30.90	30.68	27.97
70	31.30	29.49	30.66	31.93	32.53	32.08	31.88	31.36	31.03	30.81	28.49
75	31.71	29.74	31.00	32.17	32.80	32.36	32.11	31.77	31.58	31.06	28.68
80	32.07	29.80	31.69	32.42	33.02	32.62	32.41	32.07	31.88	31.32	29.22
85	32.48	30.07	31.94	32.67	33.25	33.19	32.63	32.47	32.15	31.82	29.43
90	32.94	30.33	32.42	33.20	33.61	33.71	32.81	33.20	32.48	32.82	29.96
95	33.60	31.54	33.42	33.74	34.17	34.57	33.15	33.63	32.79	33.41	30.46
Mean	29.77	28.13*	29.80*[1,10]	30.56*[1,10]	30.92*[1,9,10]	30.14*[1,10]	30.54*[1,10]	30.03*[1,10]	29.65*[10]	29.62*[10]	26.98
SD	2.71	2.57	2.25	2.31	2.43	3.36	2.03	2.49	2.35	2.31	2.30
n	972	47	94	103	109	123	108	123	77	92	96
Percentile	**All**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**87**	**87+**
5	22.31	20.70	23.31	21.97	22.11	22.82	22.98	21.82	23.05	22.36	20.54
10	23.73	22.08	23.81	23.63	23.48	24.50	24.19	25.31	25.10	23.84	22.21
15	24.70	23.01	24.57	24.55	25.64	25.40	24.91	26.07	26.00	24.45	23.36
20	25.36	23.45	25.45	25.24	26.26	25.65	25.50	26.63	26.16	24.84	23.95
25	25.72	23.75	25.67	25.83	26.59	26.45	25.93	26.92	27.06	25.06	24.51
30	26.20	24.24	25.82	26.24	26.85	26.90	26.49	27.07	27.16	25.54	24.88
35	26.61	24.60	26.05	26.76	27.31	27.19	26.62	27.26	27.44	25.74	25.36
40	26.93	25.15	26.58	27.15	27.60	27.58	26.87	27.76	27.68	26.07	25.59
45	27.21	25.30	26.85	27.37	28.07	27.91	27.01	27.88	27.81	26.26	25.97
50	27.52	25.45	27.07	27.64	28.44	28.32	27.37	28.20	28.23	26.76	26.25
55	27.87	25.52	27.30	28.00	28.76	28.52	27.54	28.56	28.39	27.50	26.41
60	28.27	25.68	27.59	28.26	29.00	28.87	28.27	29.16	28.95	27.68	26.85
65	28.61	26.17	27.79	28.59	29.27	29.21	28.63	29.84	29.25	28.29	27.06
70	29.03	26.45	28.20	28.79	29.69	29.51	29.33	30.23	29.70	28.60	27.55
75	29.45	26.78	28.54	29.19	30.29	30.13	29.81	30.62	29.93	28.91	28.13
80	29.91	27.32	29.10	29.55	30.67	30.40	30.29	30.81	30.32	29.53	28.74
85	30.49	27.55	29.53	29.92	31.07	30.64	30.86	30.97	30.52	29.71	29.47
90	31.13	27.92	30.79	30.84	32.17	31.82	31.52	32.45	31.06	30.10	30.99
95	32.56	29.21	32.08	31.40	32.99	32.76	32.78	34.10	32.04	31.75	33.16
Mean	27.53	25.27	27.09[1]	27.39[1]	28.22[1,10]	28.09[1,10]	27.69[1]	28.45[1,10]	28.11[1,10]	26.98[1]	26.37
SD	2.96	2.19	2.63	2.82	3.01	2.96	2.92	3.06	2.64	2.67	3.32
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

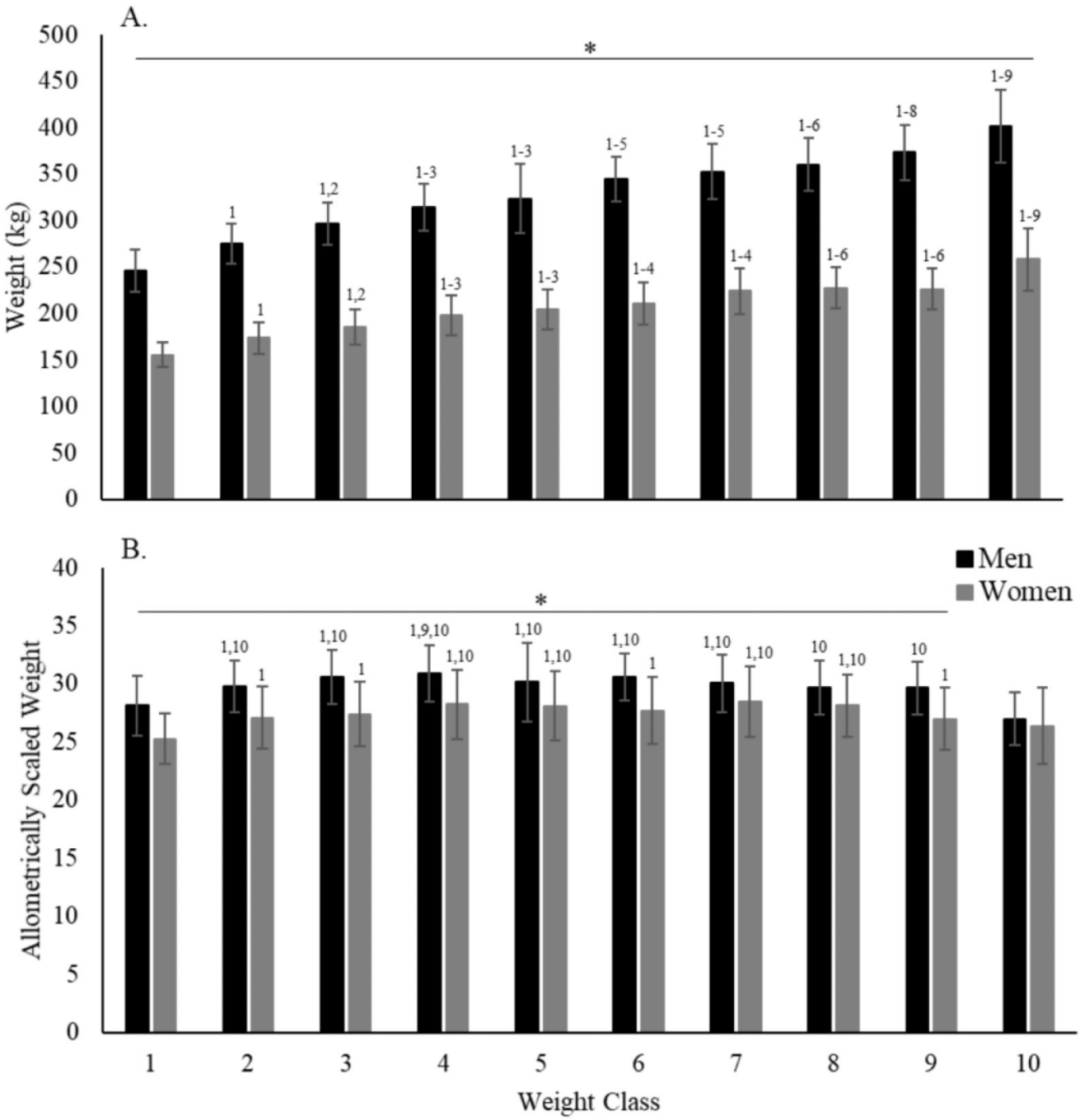

Figure 3. Means and standard deviations for A) absolute and B) allometrically scaled total for men and women by weight class. *Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men (top) and women (bottom) by weight class (kg).

Percentile	All	55	61	67	73	81	89	96	102	109	109+
5	344.42	333.48	354.16	346.15	344.94	307.04	352.26	336.07	336.60	347.91	350.80
10	360.02	348.86	367.30	360.02	362.57	335.24	362.78	356.15	360.27	355.17	363.50
15	368.88	364.77	372.18	369.00	376.56	352.72	375.46	366.74	368.70	363.50	376.32
20	375.98	366.21	375.50	381.38	384.22	367.06	381.15	377.78	373.82	371.83	379.08
25	381.86	367.29	377.95	387.89	387.45	379.97	384.56	381.79	375.47	377.65	384.76
30	386.55	371.81	385.27	392.99	392.09	386.37	390.16	385.37	381.81	383.70	390.25
35	391.69	374.50	390.74	396.70	392.65	389.41	392.30	391.51	387.43	393.58	395.37
40	395.24	376.99	393.15	400.90	398.60	394.76	398.84	394.88	393.14	400.25	399.78
45	399.34	379.39	394.96	403.00	402.10	397.61	403.53	396.95	397.75	405.18	403.96
50	403.23	385.81	398.42	407.26	410.95	402.49	407.44	399.83	403.78	409.44	406.19
55	406.62	388.08	399.94	409.21	414.36	404.85	410.41	403.37	406.30	413.99	412.53
60	411.05	389.97	403.53	415.59	419.14	410.56	413.06	408.77	410.89	415.65	416.61
65	415.12	394.00	406.44	416.95	421.87	416.02	416.68	413.18	414.84	418.07	423.44
70	418.98	400.53	408.43	420.65	426.24	420.41	420.25	417.11	416.51	419.52	426.41
75	423.37	403.58	412.94	423.71	429.80	423.96	423.14	422.45	422.89	422.66	430.78
80	427.00	404.82	421.95	427.20	432.67	427.43	426.61	426.70	428.37	426.16	436.60
85	432.03	408.21	425.68	430.41	435.80	434.85	430.13	431.55	431.46	432.63	441.30
90	437.24	411.65	432.04	437.35	440.33	441.76	432.37	440.64	436.42	447.38	453.60
95	447.83	428.45	445.31	444.46	447.80	453.00	436.55	447.25	438.25	455.33	465.58
Mean	400.05	381.97*	397.14*	402.73*[1]	405.18*[1]	394.85*	402.31*[1]	399.14*	397.91*	403.07*[1]	407.16*[1]
SD	33.88	34.81	29.59	30.23	31.80	44.10	26.81	33.03	31.55	31.62	37.14
n	972	47	94	103	109	123	108	123	77	92	96
Percentile	**All**	**45**	**49**	**55**	**59**	**64**	**71**	**76**	**81**	**87**	**87+**
5	216.59	213.93	233.88	214.74	212.42	216.65	216.23	204.84	216.50	210.77	201.32
10	232.05	228.00	239.19	230.30	225.49	232.90	227.55	237.55	235.81	224.35	225.47
15	239.07	237.45	246.77	238.82	246.09	241.01	234.23	244.86	244.23	230.85	235.46
20	244.61	242.43	255.43	246.04	252.35	243.36	240.26	250.02	245.74	234.38	242.12
25	250.04	244.96	257.39	251.95	255.44	251.09	244.13	252.60	254.22	236.21	247.65
30	254.05	249.96	258.94	255.38	257.94	255.50	249.15	254.10	254.97	240.96	249.77
35	256.76	254.34	261.65	261.01	262.63	258.01	250.44	255.90	257.71	242.74	254.05
40	260.13	260.38	266.47	264.38	264.89	261.93	252.84	260.57	259.91	246.04	259.58
45	263.26	261.73	269.56	266.71	269.53	265.02	254.29	261.64	261.14	247.90	261.37
50	266.28	263.26	271.38	269.04	273.31	268.98	257.32	264.63	265.22	252.44	266.67
55	269.78	264.58	273.88	272.83	276.16	270.51	258.99	268.03	266.48	258.64	269.83
60	273.15	267.47	277.61	274.97	278.39	274.08	265.91	273.67	272.05	261.33	274.63
65	276.82	270.54	279.16	278.68	281.38	277.04	269.19	280.07	274.77	266.29	276.27
70	280.09	272.79	282.91	280.60	285.19	280.01	275.87	283.76	279.07	269.83	279.15
75	283.54	277.02	287.15	284.47	291.02	285.93	280.37	287.36	281.00	272.88	283.77
80	287.62	281.70	291.95	287.97	294.46	288.35	285.10	289.18	284.67	278.73	289.44
85	291.78	284.16	296.54	291.56	298.24	290.76	290.71	290.67	286.54	280.38	291.61
90	300.22	288.91	311.37	300.84	309.48	301.78	296.29	304.51	291.81	283.74	314.83
95	311.47	301.95	321.81	305.62	316.70	310.68	308.20	320.05	300.92	299.47	331.77
Mean	265.78	261.17	272.14	266.97	271.13	266.60	260.59	267.02	263.96	254.40[2,4]	265.48
SD	27.97	22.73	26.33	27.38	28.84	28.13	27.46	28.74	24.85	25.19	33.36
n	890	45	96	118	133	118	110	67	68	63	72

**Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. Superscript numbers indicate significant differences with the associated weight class previously listed ($p \leq 0.05$).*

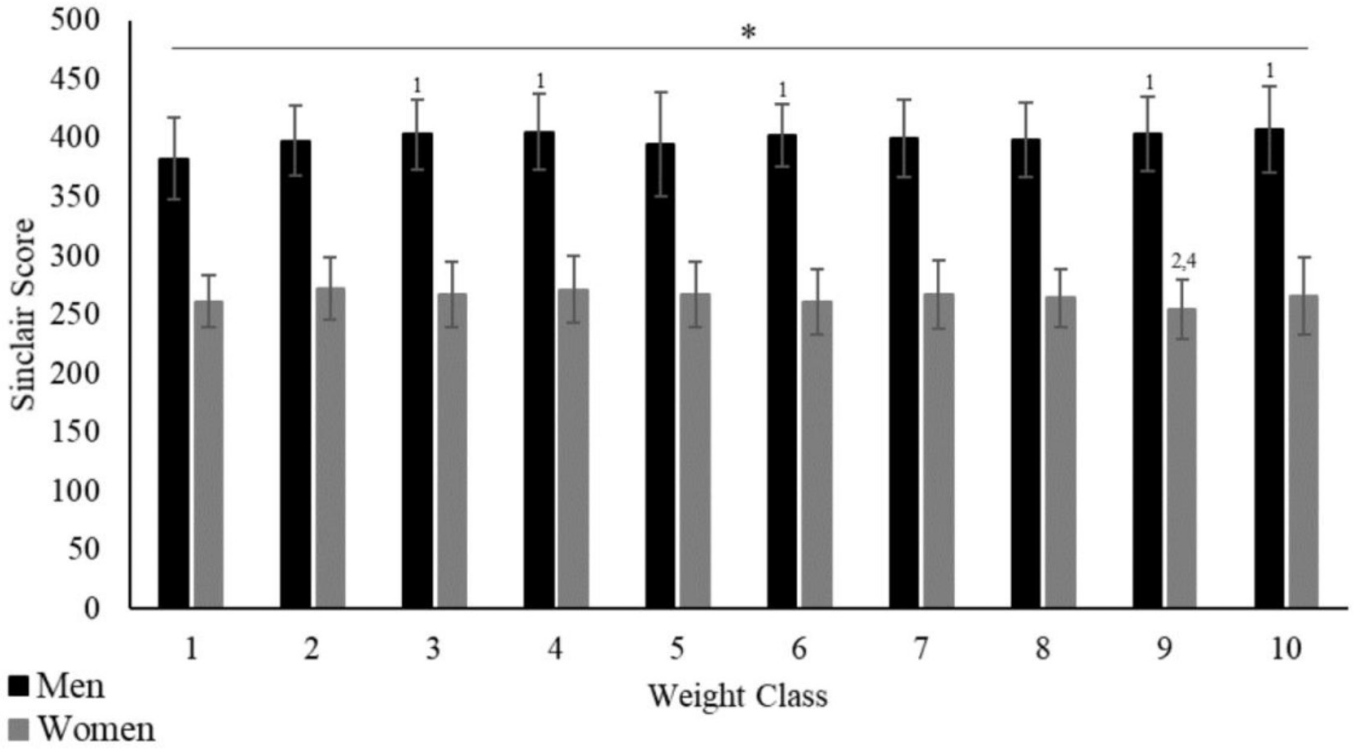

Figure 4. Means and standard deviations for Sinclair scores for men and women by weight class. *Indicates greater than other gender. [1]55 kg for men, 45 kg for women; [2]61 kg for men, 49 kg for women; [3]67 kg for men, 55 kg for women; [4]73 kg for men, 59 kg for women; [5]81 kg for men, 64 kg for women; [6]89 kg for men, 71 kg for women; [7]96 kg for men, 76 kg for women; [8]102 kg for men, 81 kg for women; [9]109 kg for men, 87 kg for women; [10]109+ kg for men, 87+ kg for women. 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 men and women.

Lift	Men	Women
Snatch	0.5513	0.4690
Clean & Jerk	0.5327	0.4853
Total	0.5411	0.4781

There was a significant gender x weight class interaction for allometrically scaled clean & jerk ($p < 0.001$, $\eta^2 = 0.019$). The men were stronger than the women across all weight classes ($p < 0.001$, $d \geq 0.804$). Within the men, 55 < 61, 67, 73, 81, 89, 96 ($p \leq 0.017$, $d \geq 0.646$), 109 < 73 ($p = 0.033$, $d = 0.541$), and 109+ < 61, 67, 73, 81, 89, 96, 102, 109 ($p < 0.001$, $d \geq 1.054$), with no other differences ($p \geq 0.082$, $d \leq 0.608$). Within the women, 45 < 49, 55, 59, 64, 71, 76, 81 ($p \leq 0.010$, $d \geq 0.767$), and 87+ < 59, 64, 76 ($p \leq 0.027$, $d \geq 0.450$).

There was a significant gender x weight class interaction for absolute total ($p < 0.001$, $\eta^2 = 0.080$). The men were stronger than the women across all weight classes ($p < 0.001$, $d \geq 3.920$). Within the men, 55 < 61 < 67 < 73, 81 < 89, 96, 102 < 109 < 109+ ($p \leq 0.043$, $d \geq 0.456$; note: 89 < 102, $p = 0.003$, $d = 0.596$). Within the women, 45 < 49 < 55 < 59, 64, 71 < 76, 81, 87 < 87+ ($p \leq 0.046$, $d \geq 0.603$; note: 59 < 71, $p = 0.004$, $d = 0.603$; 71 = 76, $p = 0.050$, $d = 0.556$).

There was a significant gender x weight class interaction for allometrically scaled total ($p < 0.001$, $\eta^2 = 0.019$). The men were stronger than the women for weight classes 1 – 9 ($p \leq 0.001$, $d \geq 0.566$), with no differences for weight class 10 ($p = 0.149$, $d = 0.214$). Within the men, 55 < 61, 67, 73, 81, 89, 96 ($p \leq 0.022$, d ≥ 0.672), 109 < 73 ($p = 0.028$, $d = 0.548$), and 109+ < 61, 67, 73, 81, 89, 96, 102, 109 ($p < 0.001$, $d \geq 1.098$). Within the women, 45 < 49, 55, 59, 64, 71, 76, 81, 87 ($p \leq 0.049$, $d \geq 0.700$), and 87+ < 59, 64, 76, 81 ($p \leq 0.006$, $d \geq 0.547$).

There was a significant gender x weight class interaction for Sinclair scores ($p = 0.003$, $\eta^2 = 0.013$). The men were stronger than the women across all

weight classes ($p < 0.001$, $d \geq 3.467$). Within the men, 55 < 67, 73, 89, 109, 109+ ($p \leq 0.008$, $d \geq 0.635$). Within the women, 49 < 87 ($p = 0.018$, $d = 0.689$), and 59 < 87 ($p = 0.018$, $d = 0.618$).

DISCUSSION

This study is the first to provide percentile rank values for absolute, allometrically scaled, and Sinclair scored OW performance with the weight classes implemented in 2018 by the IWF. Based on the results of the polynomial regression analyses in the present study, and the decrease in relationships between body weight and OW performance measures after allometric scaling, these results support the use of allometric scaling over ratio scaling due to the lack of consistent linear relationships between body weight and absolute snatch, clean & jerk, and total weightlifting scores. The present study also demonstrates weight class- and gender-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 weightlifting performance. All in all, OW coaches and competitors may use the calculated percentile rankings and allometric scaling parameters to assess absolute and body weight normalized weightlifting results for elite level Olympic Weightlifters, or for those desiring to compete at this level.

No previous studies have published percentile rank values for IWF senior competitors, although previous studies and texts have provided percentile rankings for the Olympic lifts and their derivatives in other athletic populations (Haff & Triplett, 2016; Hoffman, 2006). Although OW coaches and competitors are well-aware of metrics such as current world records and results from previous weightlifting competitions, it may be beneficial to have published percentile metrics by which performance may be compared against independent of the specific competition or world record. To address this, the present study includes percentile rankings for the snatch, clean & jerk, and total results from IWF Senior World Championships competitors, separated by weight class and gender. Furthermore, the present study provides percentile rankings for allometrically scaled results and Sinclair scores, which may be beneficial for coaches and competitors when making decisions about the appropriate weight class for maximal performance for a lifter. Thus, the present data provides a method by which coaches and competitors may quantify and compare OW performance for IWF senior competitors or potential competitors.

It is commonplace to normalize performance measures by dividing absolute performance by body weight (ratio scaling) to account for the potential confounding influence body weight may have on performance differences. However, one of the underlying assumptions of ratio scaling is a linear model of best fit between the two variables (Jaric et al., 2005; Nevill et al., 1992; Nevill & Holder, 1995). To test for this in the present study, polynomial regression analyses were performed to determine the model of best fit between body weight and absolute OW performance (snatch, clean & jerk, and total). For men and women, all relationships between body weight and absolute OW performance were quadratic or cubic, none exhibited a linear model of best fit. The use of allometric scaling is further supported by the decrease in correlation coefficients, both in terms of significance and magnitude of relationships, for the relationships between body weight and absolute weightlifting performance after allometric scaling. Of note, the same results were true when the Sinclair scores were calculated. However, since the Sinclair score calculation only takes into consideration the total (International Weightlifting Federation, n.d.-b; Sinclair, 1985), and not the individual lifts, the allometric scaling parameters in the present study provide further metrics by which coaches and practitioners may normalize OW performance to body weight.

Although previous studies have determined that body weight normalization techniques are important to consider when examining OW performance (Batterham & George, 1997; Marković & Sekulić, 2006; Stone et al., 2005), none have provided weight class-specific comparisons of absolute and body weight normalized performance. In the present study, there were weight class-specific differences for absolute weightlifting performance for men and women. In general, the weight lifted for the snatch, clean & jerk, and the total increased with weight class, such that the heaviest weight classes were the strongest. These results are not surprising as typically, lifters in heavier weight classes tend to have greater overall muscle mass, leading to greater strength and power output (Garhammer, 1980; Ikai & Fukunaga, 1968; Markovic & Jaric, 2004). Worth noting, among the middle weight classes (73 – 102 kg for men, 59 – 81 kg for women), many of these differences disappeared, suggesting that absolute OW performance differences may be more extreme in the heaviest and lightest weight

classes, while the middle weight classes may have similar absolute performance. Interestingly, when allometrically scaled, the lightest (55 kg for men, 45 kg for women) and heaviest (109+ kg for men, 87+ kg for women) weight classes tended to have the lowest performance for the snatch, clean & jerk, and total, with no differences across other weight classes. Therefore, these results suggest that lifters in the heaviest and lightest weight classes have lower strength per unit of body weight, and potentially muscle mass. However, future studies should consider quantifying muscle mass to include as a potential allometric parameter to provide further insight.

Currently, the IWF utilizes the Sinclair coefficient calculation to provide comparisons of the weight lifted while controlling for the influence of body weight (International Weightlifting Federation, n.d.-b; Sinclair, 1985). When using this method, the present results demonstrated that the 55 kg class in the men had lower scores than five other weight classes, while nearly all weight class-specific differences among the women disappeared. Thus, it appears that the Sinclair score calculation may effectively account for the influence of body weight on absolute weightlifting performance when considering the total. However, since the Sinclair calculation only takes into account the total lifted, the allometric scaling parameters in the present study may provide coaches and practitioners a method to normalize performance for the individual lifts. When combined, allometric scaling and Sinclair scores, in addition to absolute OW performance, may provide a holistic view of overall OW performance.

The current weight classification system for the IWF involves 10 weight classes for men and 10 weight classes for women, which allows comparisons from lightest to heaviest weight classes across gender. Regarding gender-specific comparisons, the men were stronger than the women across all weight classes for absolute performance for the snatch, clean & jerk, and total. When allometrically scaled, men remained stronger than the women for clean & jerk and all but the heaviest weight class for total, which was similar for gender-related comparisons of Sinclair scores. However, allometric scaling eliminated nearly all differences between men and women for the snatch. It is possible that, due to the highly technical nature of the snatch, underlying muscle mass exerts less of an influence on performance than motor coordination. This potentially suggests that the clean & jerk is more dependent on body weight, and underlying muscle mass, since men were still stronger than women after accounting for body weight via allometric scaling. Although men typically exhibit greater muscle mass than women, differences in muscle strength tend to disappear, or at least decrease in magnitude, when accounting for muscle mass (Bishop et al., 1987; Castro et al., 1995; Heyward et al., 1986; Nimphius et al., 2019; Roberts et al., 2020; Schantz et al., 1983; Welle et al., 2008). Interestingly, in powerlifters, Kataoka et al. (2023) found that men were stronger than women even after matching groups for muscle thickness, suggesting that in lifting sports (e.g., Olympic Weightlifting and Powerlifting), men may have greater strength relative to muscle mass. Although muscle mass was not quantified in the present study, greater body weight in resistance trained individuals does tend to result in greater underlying muscle mass, which may be evident in IWF competitors. However, future studies should consider assessing the influence of total body weight vs. muscle mass on differences in weightlifting performance for competitive weightlifters, particularly when considering gender-specific differences. Thus, the present results indicate that while allometric scaling may account for gender-related differences for the snatch, neither allometric scaling nor Sinclair coefficient calculations account for gender-related differences in clean & jerk and total performance.

In conclusion, the present study provides percentile rankings based on gender and weight class, which coaches and practitioners may use to gauge performance level in elite-level Olympic weightlifters. Not only did the present study provide percentile rankings based on absolute performance, but also allometrically scaled performance and Sinclair scores. Thus, coaches and practitioners may use these data to examine weightlifting performance relative to body weight. Interestingly, the present results demonstrate weight class-specific differences for absolute weightlifting performance, which were modified with allometric scaling such that individuals in the middle weight classes tended to outperform those in the heavier and lighter weight classes. Furthermore, men were stronger than the women for absolute weightlifting performance, but when accounting for body weight, men and women had similar snatch performance, while men remained stronger for the clean & jerk and total. This provides unique insight regarding the role that body weight, and potentially underlying muscle mass, play in weight class- and gender-specific differences of OW performance. Thus, the present results provide coaches and practitioners percentile rankings and allometric parameters that may be used to assess

weightlifting performance for elite-level weightlifting competitors.

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DATA AVAILABILITY STATEMENT

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

DISCLOSURE STATEMENT

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

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