Differences in Strength Performance Between Novice and Elite Athletes: Evidence From Powerlifters

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Abstract

Latella, C, van den Hoek, D, and Teo, WP. Differences in strength performance between novice and elite athletes: Evidence from powerlifters. *J Strength Cond Res* 33(7S): S103–S112, 2019—Strength forms an integral part of many sports. In particular, powerlifting success is determined solely by maximal strength, providing a unique opportunity to investigate the differences and potential factors influencing novice and elite competitors. We evaluated performance from 2,137 competitors between local (LOC), national (NAT), and international (INT) competitions. Results were analyzed by using the total (TOT) competition score within weight classes and age categories. Cohen's *d* effect sizes and 95% confidence intervals were used to detect differences within categories between LOC, NAT, and INT competitions. The coefficient of variation (CV) was used to determine the absolute variability. A moderate to large increase in performance was observed for all weight classes between LOC and NAT (men; $d = 0.76$, women; $d = 1.09$). No meaningful differences were observed between LOC and NAT, and NAT and INT when compared using age. No meaningful differences were observed between NAT to INT competitions when compared using weight classes. The CV was not different across competition level (CV = 17.4–22.9%) categories. Several internal (athlete) and external (environmental) factors are likely to explain these findings. Therefore, factors such as training experience, performance variability, body composition, anthropometric characteristics, and competition pressure that may influence strength performance should also be considered in both training phases and during competition. Collectively, the results offer novel information regarding the difference in strength performance between novice, subelite, and elite strength athletes. Strength and conditioning professionals should consider these factors when working with various athletes where maximal strength is an important determinant of success.

Key Words competition, squat, bench press, deadlift, male, female

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Introduction

Strength is a fundamental component of many athletic disciplines. In sports such as powerlifting (PL), maximal strength is the key, if not the sole determinant of success. In competition, "raw" PL (i.e., knee sleeves and lifting belt only) makes up most competitions and competitors. Individuals who perform well at local (LOC) competitions are then eligible to partake in national (NAT) competitions and ultimately qualify for international (INT) championships against other nations. However, the differences between, the variability of, and potential intrinsic and extrinsic factors influencing the performance of strength athletes at each level of competition are not well-understood.

Despite the growing popularity of PL, there is a scarcity of specific research available for strength and conditioning coaches and athletes. Of the available evidence, the majority has focussed on training practices (13,41), tapering strategies (16,38), lift kinematics (18), body composition and anthropometry (24,25,27), and injury rates (2,10,39). From a competition perspective, only a handful of authors have evaluated performance data from international championship events (1,3,9,23,37). Although these articles provide an interesting insight into the different aspects of PL, specific information regarding the differences in performance between novice and elite competitors are lacking.

Table 1. Female scores for each lift.*

	47 kg	52 kg	57 kg	63 kg	72 kg	84 kg	84+ kg
LOC							
SQ							
Grp	86.2 ± 16.7	95.4 ± 19.0	103.5 ± 23.0	104.0 ± 20.8	113.4 ± 23.0	119.5 ± 22.5	129.2 ± 26.7
Max	120.0	130.0	160.0	160.0	182.5	182.5	220.0
BP							
Grp	51.0 ± 12.1	53.4 ± 10.3	58.1 ± 13.7	58.3 ± 10.9	61.4 ± 11.9	65.4 ± 12.9	69.3 ± 13.0
Max	70.0	80.0	87.5	92.5	90.0	95.0	115.5
DL							
Grp	114.8 ± 14.2	120.3 ± 21.4	126.6 ± 23.7	129.0 ± 22.8	138.1 ± 25.1	141.0 ± 23.1	150.4 ± 23.8
Max	145.0	160.0	187.5	193.0	208.0	211.0	215.0
TO							
Grp	251.9 ± 39.5	269.1 ± 46.6	288.2 ± 56.8	291.2 ± 50.2	312.9 ± 56.2	325.8 ± 52.3	349.0 ± 58.0
Max	335.0	345.0	435.0	412.5	470.0	405.0	542.5
NAT							
SQ							
Grp	107.7 ± 17.8	113.5 ± 13.3	134.1 ± 10.6	116.5 ± 39.9	125.4 ± 42.4	133.8 ± 62.7	178.3 ± 71.5
Max	125.5	127.5	157.5	165.0	175.0	195.0	220.0
BP							
Grp	66.0 ± 16.3	62.5 ± 10.6	78.4 ± 7.8	63.3 ± 18.7	72.9 ± 17.6	80.0 ± 33.1	95.8 ± 22.4
Max	78.0	80.0	90.0	87.5	90.0	110.0	115.5
DL							
Grp	131.0 ± 9.0	147.0 ± 5.4	163.3 ± 16.3	139.0 ± 32.8	147.9 ± 48.6	158.5 ± 56.2	177.5 ± 50.2
Max	140.5	152.5	186.0	187.5	202.5	211.0	215.0
TO							
Grp	304.7 ± 35.6	323.0 ± 21.7	376.1 ± 26.0	318.8 ± 89.0	346.3 ± 107.7	372.2 ± 150.8	451.7 ± 140.8
Max	338.0	350.0	431.0	435.0	465.0	490.0	542.5
INT							
SQ							
Grp	97.0 ± 19.0	112.6 ± 23.3	115.7 ± 26.3	123.0 ± 28.8	135.2 ± 25.8	146.3 ± 31.2	170.1 ± 40.7
Max	137.5	156.5	174.5	165.5	196.0	206.5	250
BP							
Grp	56.9 ± 14.4	66.2 ± 15.9	67.5 ± 17.2	70.9 ± 17.4	75.9 ± 18.2	82.8 ± 20.1	94.2 ± 23.3
Max	95.5	110.5	107.5	112.5	130.0	135.0	145.0
DL							
Grp	122.3 ± 18.4	132.6 ± 27.8	143.2 ± 25.7	146.1 ± 23.8	158.0 ± 27.9	165.6 ± 28.0	173.8 ± 27.4
Max	170.0	182.5	187.5	200.0	237.5	215.0	220.0
TO							
Grp	276.2 ± 47.7	311.4 ± 60.8	326.1 ± 62.3	340.0 ± 58.7	369.0 ± 67.9	394.7 ± 74.7	438.2 ± 86.5
Max	372.5	423.0	462.0	457.5	532.5	535.0	615.0

*SQ = squat; Grp = group scores presented in kg (mean ± *SD*); Max = maximum score presented in kg as highest winning score for each respective category; BP = bench press; DL = deadlift and overall; TO = total for each weight class presented for; LOC = local; NAT = national; INT = international events.

Table 2. Male scores for each lift.*

	59 kg	66 kg	74 kg	83 kg	93 kg	105 kg	120 kg	120+ kg
LOC								
SQ								
Grp	141.7 ± 46.1	160.4 ± 23.4	172.7 ± 33.2	182.2 ± 31.8	197.4 ± 30.3	202.6 ± 35.2	213.7 ± 44.5	254.6 ± 78.7
Max	220.0	220.0	245.0	260.0	277.5	280.0	310.0	470.0
BP								
Grp	88.6 ± 21.1	101.5 ± 17.9	111.3 ± 23.5	119.9 ± 20.8	128.4 ± 20.2	136.1 ± 24.7	138.8 ± 28.5	161.7 ± 39.1
Max	125.0	145.0	172.5	175.0	177.5	212.5	207.5	270.0
DL								
Grp	169.6 ± 41.1	191.0 ± 24.1	206.6 ± 31.2	215.5 ± 31.0	229.2 ± 32.8	238.1 ± 38.1	243.1 ± 36.1	264.1 ± 56.2
Max	226.0	245.0	285.0	300.0	316.5	325.0	317.5	325.5
TO								
Grp	399.9 ± 104.0	452.8 ± 55.8	490.5 ± 82.5	517.6 ± 76.7	555.1 ± 76.2	577.0 ± 88.3	595.6 ± 100.6	680.4 ± 168.4
Max	531.0	605.0	677.5	685.0	741.0	766.0	800.0	1,070.0
NAT								
SQ								
Grp	200.6 ± 29.8	163.5 ± 61.2	206.7 ± 28.6	205.8 ± 58.9	240.3 ± 61.7	196.3 ± 73.4	247.5 ± 72.7	291.3 ± 59.9
Max	245.0	226.0	227.5	290.5	280.0	275.0	320.0	347.5
BP								
Grp	112.7 ± 13.4	104.6 ± 36.4	135.0 ± 21.0	135.6 ± 32.2	157.5 ± 31.9	130.8 ± 42.9	160.4 ± 43.7	194.6 ± 36.9
Max	130.5	137.5	165.0	185.0	200.0	190.0	215.0	240.5
DL								
Grp	209.4 ± 36.7	198.8 ± 43.8	238.3 ± 32.5	238.3 ± 61.8	276.8 ± 67.8	240.4 ± 65.4	276.1 ± 58.2	288.3 ± 46.2
Max	232.5	250.0	275.0	302.5	318.0	312.5	345.0	352.5
TO								
Grp	522.6 ± 18.7	466.8 ± 139.8	580.0 ± 77.2	579.7 ± 145.9	674.6 ± 158.4	567.5 ± 178.0	683.9 ± 165.7	774.1 ± 135.8
Max	545.5	603.5	645.0	740.5	772.5	737.5	865.0	927.5
INT								
SQ								
Grp	156.1 ± 37.8	179.1 ± 36.2	200.2 ± 35.5	217.1 ± 45.3	232.9 ± 42.0	247.8 ± 46.8	251.2 ± 56.5	282.7 ± 76.7
Max	240.0	250.0	270.0	292.5	325.5	332.0	386.0	470.0
BP								
Grp	102.0 ± 23.3	17.1 ± 26.4	129.3 ± 28.4	140.4 ± 29.2	154.3 ± 31.9	163.3 ± 30.6	171.0 ± 34.5	186.9 ± 43.2
Max	167.5	182.5	211.5	208.5	227.5	217.5	247.5	277.5
DL								
Grp	180.0 ± 35.4	211.5 ± 37.6	230.0 ± 37.6	248.5 ± 44.4	257.9 ± 38.1	270.1 ± 45.5	264.7 ± 47.1	280.7 ± 53.3
Max	265.0	285.0	292.5	325.0	322.5	380.0	347.5	377.5
TO								
Grp	438.1 ± 85.4	507.7 ± 90.1	559.5 ± 91.3	606.0 ± 110.9	645.0 ± 103.1	681.2 ± 111.0	686.8 ± 127.2	750.1 ± 163.2
Max	660.0	680.0	733.0	814.0	827.5	885.0	968.5	1,090.0

*SQ = squat; Grp = group scores presented in kg (mean ± *SD*); Max = maximum score presented in kg as highest winning score for each respective category; BP = bench press; DL = deadlift and overall; TO = total for each weight class presented for; LOC = local; NAT = national; INT = international events.

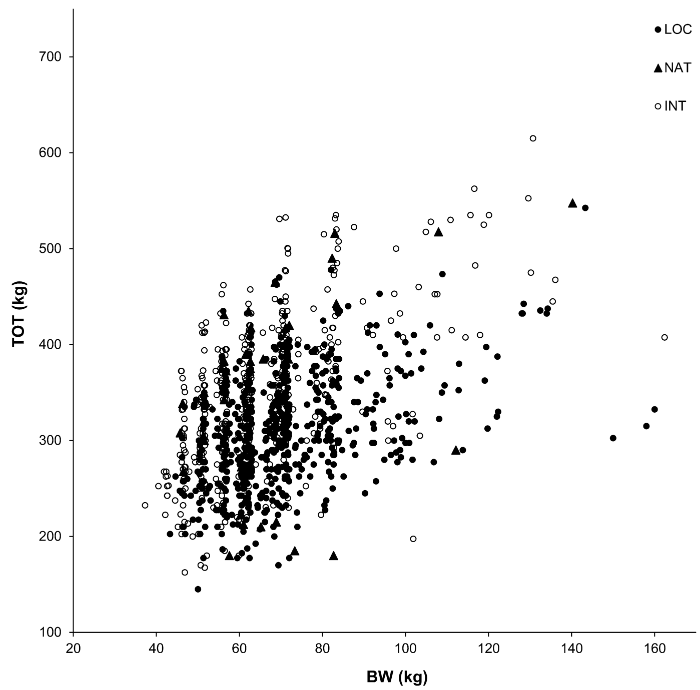

Figure 1. Representation of the TOT scores in comparison to body mass for each female competitor at LOC, NAT, and INT competitions.

In other sports (i.e., various football codes and field-based team sports), the physiological and psychological characteristics, and competition demands of amateur, subelite, and elite athletes are readily available (8,11,22,30,34,42,43). To a lesser degree, this evidence is also available in other strength/power sports (i.e., weightlifting) between LOC and NAT competitors, including athlete profiles (28) and performance differences (15,29,31,32). Collectively, the available evidence in such sports provide valid and reliable information that enables professionals to design and implement specific training programs to plan, facilitate, and monitor athletic development (17,40). However, given the growing popularity and professionalism of PL, further evidence investigating differences between novice (i.e., LOC), subelite (i.e., NAT), and elite (i.e., INT) athletes is desperately required.

Therefore, the purpose of this investigation is to evaluate the differences in strength and performance between novice, subelite, and elite strength athletes in PL. Furthermore, we aim to explore the magnitude of difference and discuss the potential factors influencing strength performance at LOC, NAT, and INT competitions for each weight class and age category in PL athletes. This information will be first of its kind in a maximal strength sport. These findings will provide evidence for strength and conditioning professionals to track athletic development and predict successful performance based on collective LOC, NAT, and INT competition results in PL and potentially other strength-related sports.

Methods

Experimental Approach to the Problem

Powerlifting competition records were collated from the January 1, 2017, to the December 31, 2017. Data were extracted from publically available databases; Powerlifting Australia, Oceania Powerlifting and the International Powerlifting Federation website(s). Given the public nature of the competition results, ethics approval was not required for this project.

Subjects

Data were collated from male and female competitors (age range 14–82 years), who competed at LOC and NAT Australian competitions or INT competitions during 2017. Data from international competitions comprised all athletes competing at the event (i.e., athletes of any nationality). Permission was granted by Powerlifting Australia to use the competition data for the proposed research, with all individuals/parent/guardians consenting to data use at the time of membership. Because of the publically available nature of the data, an ethics waiver was granted by the Deakin University Human Research Ethics Committee.

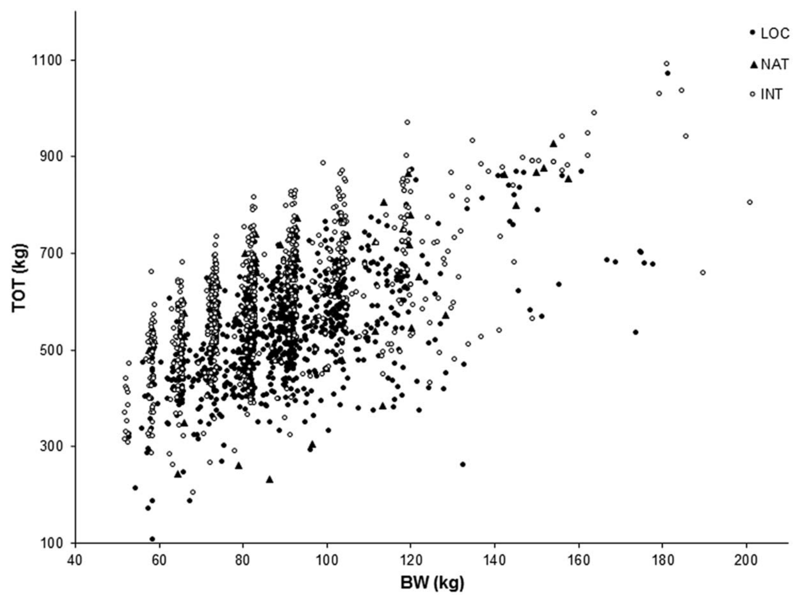

Figure 2. Representation of the TOT scores in comparison to body mass for each male competitor at LOC, NAT, and INT competitions.

Procedures

Each data set was categorized into individual weight classes for women: 47, 52, 57, 63, 72, 84, and +84 kg and men: 59, 66, 74, 83, 93, 105, 120, and +120 kg as well as age category; subjunior (SJ) <18 years; junior (JU) 18–22 years; open (OP) 23–39 years; masters I (M1) 40–49 years; masters II (M2) 50–59; masters III (M3) 60–69 years; and masters IV (M4) ≥70 years.

Statistical Analyses

Performance data were recorded for all competitors from each competition (LOC, NAT, and INT) by taking the highest successful weight lifted out of 3 attempts for the squat (SQ), bench press (BP), and deadlift (DL). The total (TOT) score was the cumulative score of the best successful SQ, BP, and DL for each competitor and used in the analysis. In addition, the maximum score in each category was recorded as the highest winning weight achieved for any lift type by any individual in that category for the entire data set in kilograms (kg). Individuals, who competed in BP or DL only, equipped competitions, or those who failed to record a TOT score were excluded from the analysis. The precision of mean differences were expressed with 95% confidence limits (95% CL), which defines the range representing the uncertainty in the true value of the (unknown) population mean. This approach is considered more applicable in applied sports settings when providing information for coaches and athletes (21). Qualitative descriptors of

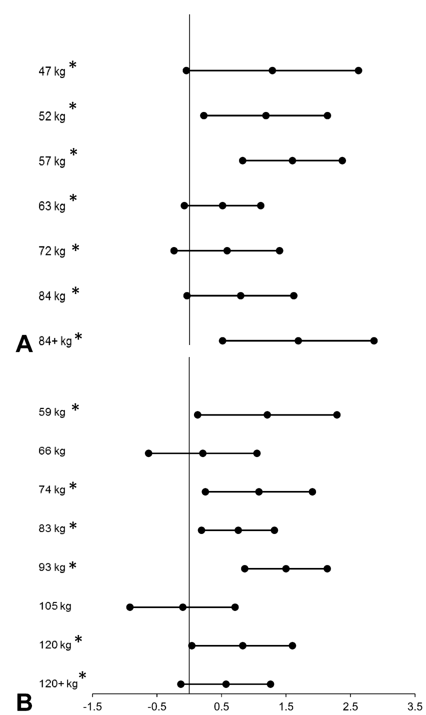

Figure 3. Effect sizes (ES) and 95% confidence limits (95% CL) between LOC (y-axis) and NAT competitions within weight classes for (A) women and (B) men, respectively. *Indicates a meaningful difference.

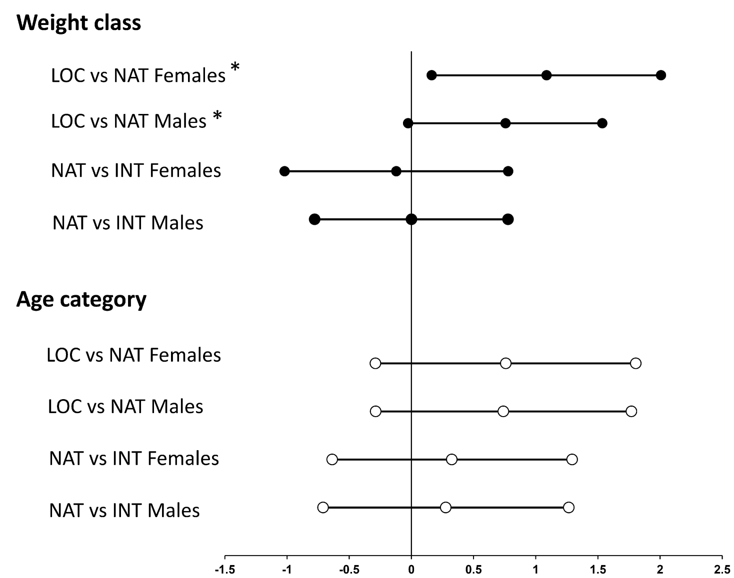

Figure 4. Overall effect sizes (ES) and 95% confidence limits (95% CL) for all competitors between LOC and NAT, and NAT and INT competitions when analyzed using weight classes and age categories. *Indicates a meaningful difference.

standardized (Cohen's *d*) effect sizes were assessed using these criteria: trivial <0.2, small 0.2–0.49, moderate 0.5–0.79, and large >0.8 (12). Effects with CLs overlapping the thresholds for small positive and small negative effects (i.e., exceeding 0.2 of the *SD* on both sides of zero) were defined as unclear, and conversely, a clear effect was defined as the 95% CL not exceeding a trivial effect size on both sides of zero (7). Clear small or larger effect sizes were defined as substantial. The coefficient of variation (CV) was initially calculated separately for each individual category using the formula *SD/*mean and multiplied by 100 to obtain CV%. Competition-level CV was obtained by averaging the CV from all individual categories at that level, and a 2-tailed independent sample *t*-test used to detect potential differences in CV between competition levels. All calculations were performed in Excel (version 2013; Microsoft Corporation, Redmond, WA, USA). Scores are displayed as the group mean ± *SD* in kilograms (kg) and are presented for women (Table 1) and men (Table 2).

Results

Descriptive Statistics

The age range of competitors was men; 15–82 years and women; 14–77 years, respectively. The body mass of individuals ranged from 52.0–201.0 kg and 37.3–162.4 kg for men and women, respectively. The data set included 2,137 different individuals across 90 competitions. The total number of competitors was 1,258 men and 879 women, respectively. The total number of individual results was as follows; LOC: 1814, NAT: 105, and INT: 1,044.

Absolute Reliability

The CV for LOC, NAT, and INT competitions was 17.4, 22.9, and 18.2%, respectively, when averaged across all weight classes. The results of an independent sample 2-tailed *t*-test showed no significant difference in the absolute variability of the data between LOC and NAT ($p = 0.18$) or NAT and INT ($p = 0.27$) competitions. The CV for LOC, NAT, and INT competitions was 20.9, 19.1, and 19.2%, respectively, when averaged across all age categories. The results of an independent sample 2-tailed *t*-test showed no significant difference in the absolute variability of the data between LOC and NAT ($p = 0.85$) or NAT and INT ($p = 0.92$) competitions.

Weight Class

Figures 1 and 2 display the individual TOT scores for women and men, respectively, in comparison with body mass.

TOT scores were higher in NAT compared with LOC competitions for women in the 47 kg (52.8 kg, $d = 1.28$, 95% CL = −0.05 to 2.61), 52 kg (53.9 kg, $d = 1.18$, 95% CL = 0.22–2.13), 57 kg (87.9 kg, $d = 1.59$, 95% CL = 0.82–2.36), 63 kg (27.6 kg, $d = 0.51$, 95% CL = −0.08 to 1.10), 72 kg (33.4 kg, $d = 0.58$, 95% CL = −0.24 to 1.39), 84 kg (46.5 kg, $d = 0.79$, 95% CL = −0.04 to 1.61), and 84+ kg (102.7 kg, $d = 1.68$, 95% CL = 0.51–2.85) weight classes, respectively (Figure 3A). An overall difference was observed for women between LOC and NAT competitions ($d = 1.09$,

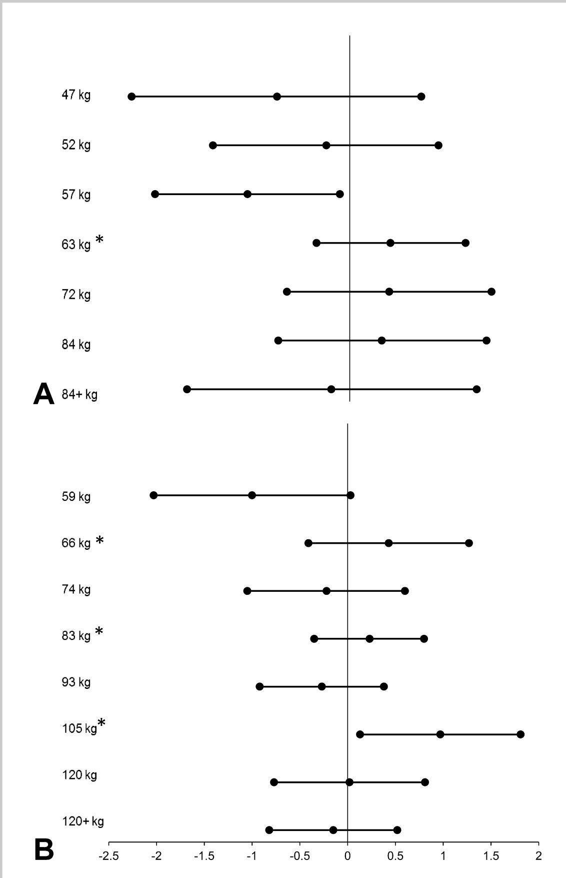

Figure 5. Effect sizes (ES) and 95% confidence limits (95% CL) between NAT (y-axis) and INT competitions within weight classes for (A) women and (B) men, respectively. *Indicates a meaningful difference.

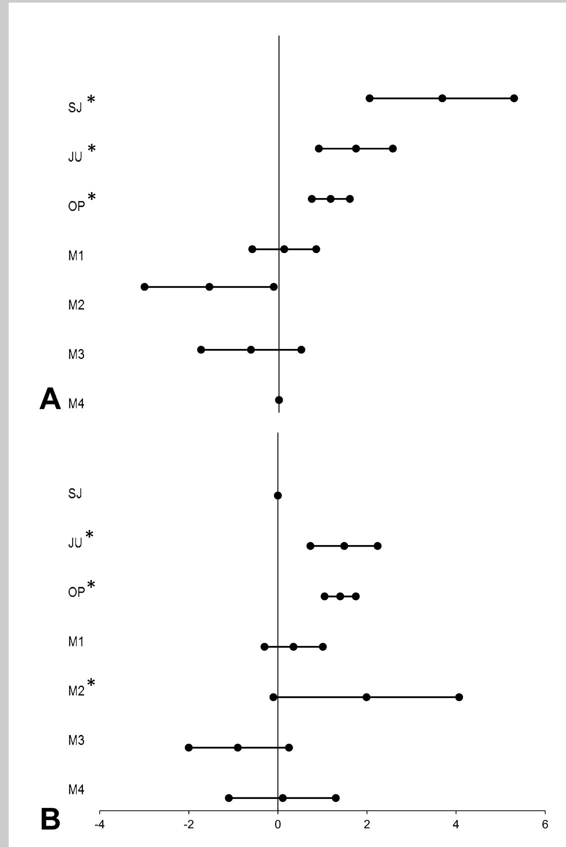

Figure 6. Effect sizes (ES) and 95% confidence limits (95% CL) between LOC (y-axis) and NAT competitions within age categories for (A) women and (B) men, respectively. *Indicates a meaningful difference.

95% CL = 0.16–2.00) (Figure 4). No difference in TOT scores were observed for INT compared with NAT competitions within weight classes (Figure 5A). No overall difference was observed for women between NAT and INT competitions ($d = -0.12$, 95% CL = −1.02 to 0.78) (Figure 4).

TOT scores were higher in NAT compared with LOC competitions for men in the 59 kg (122.7 kg, $d = 1.21$, 95% CL = 0.13–2.29), 74 kg (89.5 kg, $d = 1.08$, 95% CL = 0.25–1.91), 83 kg (62.1 kg, $d = 0.76$, 95% CL = 0.19–1.32), 93 kg (119.5 kg, $d = 1.50$, 95% CL = 0.86–2.14), 120 kg (88.3 kg, $d = 0.82$, 95% CL = 0.04–1.60), and 120+ kg (93.7 kg, $d = 0.57$, 95% CL = −0.13 to 1.26) weight classes, respectively (Figure 3B). An overall difference was observed for men between LOC and NAT competitions ($d = 0.76$, 95% CL = −0.03 to 1.54) (Figure 4). TOT scores were higher for INT compared with NAT competitions for the 105 kg (113.7 kg, $d = 0.97$, 95% CL = 0.13–1.81). (Figure 5B). No overall difference was observed for men between NAT and INT competitions ($d = 0.00$, 95% CL = −0.78 to 0.78) (Figure 4).

Age Category

TOT scores were higher in NAT compared with LOC competitions for women in the SJ (207.2 kg, $d = 3.73$, 95% CL = 2.07–5.39), JU (97.9 kg, $d = 1.76$, 95% CL = 0.91–2.60), and OP (66.9 kg, $d = 1.18$, 95% CL = 0.75–1.62) age categories, respectively. No differences were observed for the M1–M4 age categories, respectively (Figure 6A). No overall difference was observed for women between LOC and NAT competitions ($d = 0.76$, 95% CL = −0.28 to 1.81) (Figure 4). TOT scores were higher for INT compared with NAT competitions for the M1 (48.2 kg, $d = 0.77$, 95% CL = 0.03–1.51), M2 (117.0 kg, $d = 2.12$, 95% CL = 0.65–3.59), and M3 (53.9 kg, $d = 1.41$, 95% CL = 0.30–2.52) age categories, respectively. No differences were observed for the SJ, JU age categories between NAT and INT competitions (Figure 7A). No overall difference was observed for women between NAT and INT competitions ($d = 0.33$, 95% CL = −0.64 to 1.29) (Figure 4).

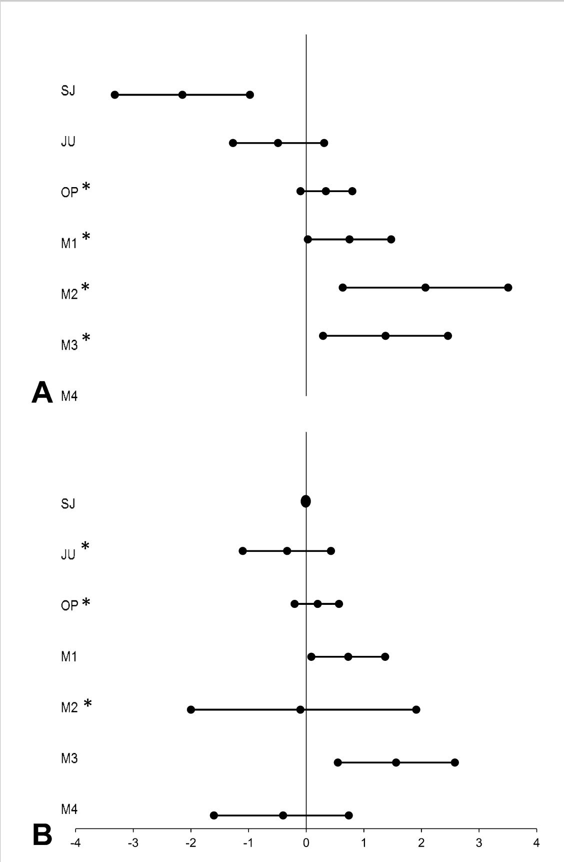

Figure 7. Effect sizes (ES) and 95% confidence limits (95% CL) between NAT (y-axis) and INT competitions within age categories for (A) women and (B) men, respectively. *Indicates a meaningful difference.

TOT scores were higher in NAT compared with LOC competitions for men in the JU (136.8 kg, $d = 1.49$, 95% CL = 0.73–2.24), OP (125.6 kg, $d = 1.40$, 95% CL = 1.05–1.75), and M2 (171.6 kg, $d = 1.99$, 95% CL = −0.10 to 4.07) age categories, respectively (Figure 6B). No overall difference was observed for men between LOC and NAT competitions ($d = 0.74$, 95% CL = −0.29 to 1.77) (Figure 4). TOT were higher for INT compared with NAT competitions for the M1 (86.5 kg, $d = 0.73$, 95% CL = 0.09–1.37), and M3 (148.3 kg, $d = 1.56$, 95% CL = 0.55–2.58) age categories, respectively. No differences were observed for the SJ, JU, M2, and M4 age categories between NAT and INT competitions (Figure 7B). No overall difference was observed for men between NAT and INT competitions ($d = 0.28$, 95% CL = −0.71 to 1.27) (Figure 4).

Discussion

To our knowledge, this is the first article to evaluate strength performance between novice, subelite and elite competitors in PL. The results suggest an overall difference between LOC and NAT competitions across weight classes for men ($d = 0.76$) and women ($d = 1.09$) while age category results were less clear. No clear effects were observed between LOC and NAT, or NAT and INT competitions when analyzed by age categories. Likewise, no clear effects were observed between NAT and INT competitions when analyzed using weight classes. In addition, we discuss several potential factors that are likely to contribute to these results. Collectively, the findings suggest that subelite powerlifters display greater strength performance compared with novice competitors; however, performances at subelite competitions were similar to elite competitions. Professionals should consider using the results to accurately track development and understand the differences between, and the potential factors affecting strength performance in sports requiring a large emphasis on maximal strength.

The results suggest a large difference in performance between LOC and NAT competitions. Although this result is not surprising and is routinely observed in other sports (33), consideration should be given regarding the underlying factors. For example, the experience level of athletes competing at LOC competitions is likely to be less than subelite or elite competitors. Although we were not able to ascertain the experience level of competitors within this study, LOC competitions are often a starting point for many first-time competitors. In particular, skill mastery and physiological adaptations result from high levels of deliberate and specific practice over considerable amounts of time designed to improve performance (14). As highlighted in long-term athlete development models, it may be more feasible to base training and performance assessment on training history rather than chronological age (4). Furthermore, potential differences in anthropometry and body composition should also be considered when interpreting these results (24,25,27). In addition, it may be argued that older lifters should have acquired much more practice than younger lifters, although it is also important to consider that this is unlikely to directly reflect the sport-specific training age. For example, an M2 athlete may have only participated in one local competition, whereas a JU athlete may have competed in several LOC, NAT, and INT competitions despite obvious differences in chronological age. Other factors such as performance variability should also be considered in human performance analyses. For example, McGuigan and Kane (32) highlight that lower ranked athletes tend to have a greater intraindividual variability of performance than higher ranked performers likely due to inconsistencies in training and effort. Although it may be possible to track within-athlete variability across multiple competitions, this was only achievable for some athletes out of the sample and therefore not considered an accurate representation of intraindividual reliability. Furthermore, the calendar year cross-sectional analysis did not have the ability to determine the training age or competition history of competitors. However, the current results showed that the absolute reliability was similar across all competition levels, and the difference between competitor scores remains similar regardless of the competition level. From a practical perspective, coaches should be aware of potential factors that separate performances of less-experienced vs. more elite strength athletes such as sport-specific training experience.

The performance of athletes at NAT and INT competitions were similar with no clear overall effects across weight classes or age categories. There are several possible explanations for these findings. First, the intraindividual variability in the performance of elite athletes were generally small as has been established in other sports (20,32,35,36). Specifically, Malcata and Hopkins (29) found that the variability in performance of elite athletes in explosive strength sports is low, ranging from 1.4 to 3.3%. Second, the relatively short training time between NAT and INT events (i.e., 2–4 months during 2017 between open and junior/masters nationals, respectively, and the Oceania championships) leaves little room for athletic progression. Moreover, improvements in performance become smaller over time according to the law of diminishing returns. In support of the current findings, it has also been demonstrated that athletes show less variability in performance within seasons than between (29). In addition, environmental factors such as increased demands of international events (i.e., travel stress, unfamiliar environment, and competition pressure) (29) may also limit or contribute the performance results observed. In fact, evidence suggests that traveling at altitude, jet lag, sleep deprivation, and disturbances in circadian rhythm have an impact on athletic performance (26,44). To compound this issue, an increase in perceived pressure, anxiety, and stress at INT events can potentially affect motor skills and attentional focus (5), which is likely to be exacerbated in individual sports (19). In particular, even a small variability in movement patterns can substantially affect performance in single-effort events (6). Therefore, the analysis suggests that the strength-based performance was similar between NAT and INT competitions; however, this result may be influenced by intrinsic and external factors in the lead up to and during competition.

Collectively, the results of this investigation offer novel evidence regarding the differences between novice and elite strength athletes, and discussion of the factors that may contribute to these results. Specifically, the analysis in PL athletes showed a large difference between LOC and NAT competitions despite similarities between NAT and INT competitions. The results suggest that performance in novice powerlifters may be affected by the training status and consistency. The similarity between NAT and INT performances suggests a low variability of subelite and elite athletes' strength in PL despite considerably a large between-competitor variance in TOT scores.

Practical Applications

Coaches should consider using this information to track development in strength athletes. Specifically, the information should be used in PL as an indicator of the performance required at each level of competition. In addition, coaches should understand that the performance of novice athletes is likely to progress rapidly, thus constant re-evaluation of strength levels may be required. Conversely, performances of subelite and elite PL strength athletes are likely to be less variable and thus should provide confidence for subelite competitors entering into international championships.

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References

1. Anton, MM, Spirduso, WW, and Tanaka, H. Age-related declines in anaerobic muscular performance: Weightlifting and powerlifting. *Med Sci Sports Exerc* 36: 143–147, 2004.
2. Aasa, U, Svartholm, I, Andersson, F, and Berglund, L. Injuries among weightlifters and powerlifters: A systematic review. *Br J Sports Med* 51: 211–219, 2017.
3. Ball, R and Weidman, D. Analysis of USA powerlifting federation data from January 1, 2012–June 11, 2016. *J Strength Cond Res* 32: 1843–1851, 2017.
4. Bayli, I and Hamilton, AAE. Key to success: Long-term athlete development. *Sports Coach* 23: 30–32, 2000.
5. Baric, R. Psychological pressure and athletes' perception of motivational climate in team sports. *Rev Psych* 1: 45–49, 2011.
6. Bartlett, R, Wheat, J, and Robins, M. Is movement variability important for sports biomechanists? *Sports Biomech* 6: 224–243, 2007.
7. Batterham, AM and Hopkins, WG. Making meaningful inferences about magnitudes. *Int J Physiol Perform* 1: 50–57, 2006.
8. Bilsborough, JC, Greenway, KG, Opar, DA, Livingstone, SG, Cordy, JT, Bird, SR, et al. Comparison of anthropometry, upper-body strength, and lower-body power characteristics in different levels of Australian football players. *J Strength Cond Res* 29: 826–834, 2015.
9. Bishop, PA, Williams, TD, Heldman, AN, and Vanderburgh, PM. System for evaluating powerlifting and other multi-event performances. *J Strength Cond Res* 32: 201–204, 2018.
10. Brown, EW and Kimball, RG. Medical history associated with adolescent powerlifting. *Pediatrics* 72: 636–644, 1983.
11. Clarke, AC, Anson, JM, and Pyne, DB. Game movement demands and physical profiles of junior, senior and elite male and female rugby sevens players. *J Sports Sci* 35: 727–733, 2017.
12. Cohen, J. A power primer. *Psychol Bull* 112: 155–159, 1992.
13. Colquhoun, RJ, Gai, CM, Walters, J, Brannon, AR, Kilpatrick, MW, D'Agostino, DP, et al. Comparison of powerlifting performance in trained men using traditional and flexible daily undulating periodization. *J Strength Cond Res* 31: 283–291, 2017.
14. Ericsson, KA. Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. *Int J Sport Psychol* 38: 4–34, 2007.
15. Fry, AC, Ciroslan, D, Fry, MD, LeRoux, CD, Schilling, BK, and Chiu, LZF. Anthropometric and performance variables discriminating elite American junior men weightlifters. *J Strength Cond Res* 20: 861–866, 2006.
16. Grgic, J and Mikulic, P. Tapering practices of Croatian open-class powerlifting champions. *J Strength Cond Res* 31: 2371–2378, 2017.
17. Hales, ME. Evaluating common weight training concepts associated with developing muscular strength: Truths or myths? *Strength Cond J* 33: 91–95, 2011.

18. Hales, ME, Johnson, BF, and Johnson, JT. Kinematic analysis of the powerlifting style squat and the conventional deadlift during competition: Is there a cross-over effect between lifts? *J Strength Cond Res* 23: 2574–2580, 2009.

19. Han, DH, Kim, JH, Lee, YS, Bae, SJ, Bae, SJ, and Lyoo, IK. Influence of temperament and anxiety on athletic performance. *J Sports Sci Med* 5: 381–389, 2006.

20. Hopkins, WG. Competitive performance of elite olympic-distance triathletes: Reliability and smallest worthwhile enhancements. *Sportscience* 9: 17–20, 2005.

21. Hopkins, WG, Hawley, JA, and Burke, LM. Design and analysis of research on sport performance enhancement. *Med Sci Sports Exerc* 31: 472–485, 1999.

22. Izzo, R and Varde, ICH. Differences by field positions between young and senior amateur soccer players using GPS technologies. *Sci Mov Health* 17: 344–352, 2017.

23. Keogh, J, Hume, PA, and Pearson, S. Retrospective injury epidemiology of one hundred competitive Oceania power lifters: The effects of age, body mass, competitive standard, and gender. *J Strength Cond Res* 20: 672–681, 2006.

24. Keogh, JWL, Hume, PA, Pearson, SN, and Mellow, P. Anthropometric dimensions of male powerlifters of varying body mass. *J Sports Sci* 25: 1365–1376, 2007.

25. Keogh, JWL, Hume, PA, Pearson, SN, and Mellow, P. Can absolute and proportional anthropometric characteristics distinguish stronger and weaker powerlifters? *J Strength Cond Res* 23: 2256–2265, 2009.

26. Leatherwood, WE and Dragoo, JL. Effect of airline travel on performance: A review of the literature. *Br J Sports Med* 47: 561–567, 2013.

27. Lovera, M and Keogh, JWL. Anthropometric profile of powerlifters: Differences as a function of bodyweight class and competitive success. *J Sports Med Phys Fit* 55: 478–487, 2015.

28. Mahoney, MJ. Psychological predictors of elite and non-elite performance in Olympic weightlifting. *Int J Sport Psych* 20: 1–12, 1989.

29. Malcata, RM and Hopkins, WG. Variability of competitive performance of elite athletes: A systematic review. *Sports Med* 44: 1763–1774, 2014.

30. Marques, L, Franchini, E, Drago, G, Aoki, MS, and Moreira, A. Physiological and performance changes in international and international judo athletes during block periodization training. *Biol Sport* 34: 371–378, 2017.

31. Mattiuzzi, C and Lippi, G. Relationship between body weight and total weight lifted in the 2013 World Weightlifting Championships. *Perform Enhancement Health* 3: 49–50, 2014.

32. McGuigan, MR and Kane, MK. Reliability of performance of elite olympic weightlifters. *J Strength Cond Res* 18: 650–653, 2004.

33. Miller, JD, Ventresca, HC, and Bracken, LE. Rate of performance change in American female weightlifters over 10 years of competition. *Int J Exerc Sci* 11: 290–307, 2018.

34. Orchard, J, Wood, T, Seward, H, and Broad, A. Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport* 1: 82–88, 1998.

35. Paton, CD and Hopkins, WG. Variation in performance of elite cyclists from race to race. *Eur J Sports Sci* 6: 25–31, 2006.

36. Paton, CD and Hopkins, WG. Competitive performance of elite olympic-distance triathletes: Reliability and smallest worthwhile enhancement. *Sportsscience* 9: 1–5, 2005.

37. Pritchard, HJ and Morton, RH. Powerlifting: Success and failure at the 2012 Oceania and 2013 classic world championships. *J Aust Strength Cond* 23: 67–70, 2015.

38. Pritchard, HJ, Tod, D, Barnes, MJ, Keogh, JWL, and McGuigan, M. Tapering practices of New Zealand's elite raw powerlifters. *J Strength Cond Res* 30: 1796–1804, 2016.

39. Siewe, J, Rudat, J, Rolinghoff, M, Schlegel, UJ, Eysel, P, and Michael, JW. Injuries and overuse syndromes in powerlifting. *Int J Sports Med* 32: 703–711, 2011.

40. Storey, A and Smith, HK. Unique aspects of competitive weightlifting: Performance, training and physiology. *Sports Med* 42: 769–790, 2012.

41. Swinton, PA, Lloyd, R, Agouris, I, and Stewart, A. Contemporary training practices in elite British powerlifters: Survey results from an international competition. *J Strength Cond Res* 23: 380–384, 2009.

42. Veale, JP, Pearce, AJ, Buttifant, D, and Carlson, JS. Anthropometric profiling of elite junior and senior Australian football players. *Int J Sports Physiol Perform* 5: 509–520, 2010.

43. Woods, CT, McKeown, I, Haff, GG, and Robertson, S. Comparison of athletic movement between elite junior and senior Australian football players. *J Sports Sci* 34: 1260–1265, 2016.

44. Youngsted, SD and O'Connor, PJ. The influence of air travel on athletic performance. *Sports Med* 28: 197–207, 1999.