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Impacts of squat attempt weight selection and success on powerlifting performance

Running Head: Squat attempt weight selection

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ABSTRACT

Background: To date, there is no evidence to support the optimal competition strategy for success in powerlifting competitions. The purpose of this study was to analyse Powerlifting (PL) competition data to assess the relationship between squat attempts, the success of each lift attempt, and weight increase between attempts, with winning.

Methods: 10,672 individual competition entries (males: $n = 6617$, females: $n = 4,055$) were included within the analysis from 'raw' Powerlifting Australia sanctioned competitions held between 2008 and 2019. We reported Cohen's d , statistical significance, 95% confidence intervals and the univariate odds of winning an event. Factors were assessed by separate simple logistic regression and reported as an odds ratio.

Results: Overall, first squat attempt weight for those who won was on average 7.0kg greater ($P < 0.001$, $d = 0.14$ [0.10, 0.18]) than for non-winners. In the total sample, athletes selected opening attempts which were an average of 92% of their achieved maximum on the day with 93.5% of competitors improving on this weight in subsequent attempts. Winners had a 0.5kg ($P < 0.001$, $d = 0.10$ [0.06, 0.14]) greater absolute increase in weight between first and second lift attempts than non-winners. Overall, ~68% of winners successfully lifted their third attempt weight compared to ~64% of non-winners ($P < 0.001$).

Conclusions: A powerlifting athlete's odds of winning a competition overall are significantly increased by selecting a larger opening squat attempt weight than competitors and completing the attempt successfully. The opening squat may be one of the most important lifts during competition.

Keywords:

Sport; strength; athlete; performance analysis; winning; competition

Abbreviations:

BP Bench press

CM Competition maximum

DL Deadlift

IPF International Powerlifting Federation

OR Odds ratio

PL Powerlifting

SQ Squat

WP World Powerlifting

INTRODUCTION

Powerlifting (PL) is a strength-based sport comprising of the squat (SQ), bench press (BP) and deadlift (DL). The objective of the PL athlete is to achieve the highest total weight lifted during competition. The ‘total’ is the sum of the best weight successfully completed for each lift-type^{1,2}. Athletes are classified into competition classes based on sex, weight and age and compete in order based on the weight chosen for each lift attempt, from lightest to heaviest. The winner of each weight class is the athlete who has the largest combined total of successful lifts and an overall best lifter for a meet is calculated using a Wilks score, and more recently the International Powerlifting Federation (IPF) formula, to account for bodyweight^{3,4}.

Understanding factors that facilitate PL performance can provide essential insight for coaches and athletes to develop evidence-based strategies for competitive success. However, despite ongoing PL performance research⁵⁻¹⁰, limited research exists regarding intra-competition variables that may contribute to success or failure on the day^{6,7}. Of the available research, it has been demonstrated that completing more successful lifts is associated with greater competitive success^{11,12}. The importance of the number of successful lift attempts is further reported by Pritchard and Morton¹¹ who found that 57% of medal finishers at the world-level completed a minimum of eight out of nine lifts compared to those who were unplaced. Specifically, during competition Coker et al.¹² reported that for each additional successful SQ attempt, Wilks score increased by ~4.76 points, and each subsequent successful BP increased Wilks score by ~8.53 points. However, the number of successful DL attempts did not appear to significantly influence Wilks score. Therefore, optimising strategies to achieve a greater number of successful SQ attempts may significantly contribute to an athlete’s odds of competitive success. It is important to note that competitions are first determined on (absolute) ‘total’ weight lifted and that the Wilks score determines placing when a tie is reached. Based

on previous research, PL athletes would need to successfully complete at least two out of three SQ attempts to achieve an equivalent increase in Wilks score as they would with a single, successful BP attempt. Pritchard and Morton (2015) also reported that the percentage of athletes achieving a successful lift on any attempt declines significantly from the first to the second, and then to the third attempt. Thus, factors such as weight increase between SQ attempts likely contribute to the decline in lift success, but this has not specifically been examined, nor is the impact on overall competition performance clear. Understanding this influence is important because currently, weight selection for each SQ attempt is largely based on coach and athlete decision making prior to, and during competition rather than empirical evidence.

Previous research has shown that only 2% of athletes who failed their first squat attempt finished in the top three of their respective categories ¹¹. Anecdotally, many coaches and athletes agree that success or failure of the first lift of the competition (i.e. opening SQ attempt) can influence the athlete's psyche. Specifically, PL athletes may lack confidence after failing their initial opening SQ attempt, increasing anxiety and reducing confidence for subsequent lift attempts. Thus, conservative weight selection strategies are favoured but are not supported by literature. Psychological momentum can play a role in many aspects of sport. In its simplest terms, this refers to "success breeding success" ¹³. As demonstrated in other sports (e.g. basketball), players are more likely to achieve success at a second free throw attempt if they had been successful at the first ¹⁴⁻¹⁶. PL athletes are not immune to these effects, especially as the number of successful attempts contributes to competition success ¹¹. Therefore, investigating opening SQ attempts (weight and success), and the influence on successive weight increase between attempts is an important but underexplored factor in PL performance.

This study aimed to specifically explore the relationship between opening SQ attempts, the weight increase between SQ attempts, the success rate of SQ attempts and the attempt that the maximum SQ occurred at on competitive success (i.e. winning) in competitive PL athletes. To date, there is no empirical evidence which reports the effect of attempt weight selection on PL competition performance. We hypothesised that athletes who won competitions would have a greater opening SQ attempt relative to other competitors, that their absolute increase in weight between attempts would be greater than non-winners and that winners would achieve a greater number of successful lifts. The information presented, and collective findings may aid coaching professionals and athletes to develop evidence-based competition strategies to optimise the odds of competitive PL success.

MATERIALS AND METHODS

Experimental approach to the problem

Individual athlete competition data was collated over an 11-year period: 23rd of November 2008 to the 11th August 2019. Powerlifting Australia data was sourced from a publicly available database (<https://www.openpowerlifting.org/>). Sanctioned competition data recorded included bodyweight, lift attempts (score and successful completion) and Wilks score. To be included in this investigation, athletes must have competed at least once in a standard, open-age or master's competitive weight class at an IPF or World Powerlifting (WP) sanctioned competition with Powerlifting Australia during the data analysis period. Additionally, athletes were also required to have their age and bodyweight recorded at time of competition and to have recorded an attempt weight for their first SQ. An ethics waiver was granted by the Human Research Ethics Committee.

Procedures

To be included within the study, athletes must have competed at least once during the data analysis period at a 'raw' Powerlifting Australia sanctioned event^{1,2}. Lift attempts for each of the three competitive lifts along with 'total' competition scores, category (age, weight class, sex) and placing for each competitor were extracted from official competition results and categorised into two groups; winners (i.e. 1st place finishers) or non-winners. Competition maximum (CM) was calculated from the greatest SQ attempt weight successfully lifted for each athlete. This was used to identify attempt weight selection relative to the athletes CM for attempt one, two and three of the SQ, respectively. This data did not include results from single lift or equipped events.

Subjects

Within the available dataset of 11,876 competition entries, age was unavailable in 1,198 cases, first lift weight for the SQ was unavailable in 39 cases, 79 cases were classified as junior weight classes and 60 cases were reported in non-standard competitive weight classes and were thus, omitted from analysis. Upon removal, 10,637 competition entries (males: n=6,594 [62%], females: n=4,043 [38%]) with a mean age \pm SD and mean body mass \pm SD of 28 years \pm 10, 89.5 \pm 18.4kg and 31 \pm 11 years, 69.5 \pm 15.9kg for males and females, respectively, across 354 competitions were included in all analyses. Individual athlete results are listed within their relevant competition weight class at the time of competition. This is important because Powerlifting Australia competition transitioned from the IPF to WP registration in late 2017, resulting in an equal number of weight classes for men and women (previously eight for men and seven for women in IPF competitions) and amendment to weight categories. As such, the number of participants in WP weight classes is limited.

Statistical analyses

All analyses were conducted using Stata statistical software version 16 (College Station TX, USA). Independent t-tests were used to compare continuous data between sexes (male/female) or winning an event (yes/no). Cohen's d and the lower and upper 95% confidence interval (d [95%CI]) were calculated and interpreted as: $d \geq 0.2$ = small effect; $d \geq 0.5$ = medium effect; $d \geq 0.8$ = large effect¹⁷. Univariate odds of winning an event based on independent variables age, sex, weight of first lift attempt [regardless of success] were assessed by separate simple logistic regression and reported as an odds ratio (OR). An odds ratio represents the relationship between an exposure and an outcome (i.e. the chances that an outcome will occur given a specific exposure). For continuous exposures (e.g. absolute increase in squat attempt weight [kg] between lift one and two), this represents the odds of an outcome (e.g. success) for each unit increase of the exposure (i.e. each kg increase). For this example, an odds ratio of 1.021 would indicate 2.1% increased odds of success for each kilogram increase between attempt one and two¹⁸. Weight of lift was considered as both absolute (kg) and relative to athlete body weight (i.e. weight of lift divided by body weight). An alpha level of 0.05 was adopted for all statistical tests.

RESULTS

Demographics

Females were three years older than males ($P < 0.001$, $d = 0.31$ [0.27, 0.35]) and had a 20.0 kg lower mean body weight ($P < 0.001$, $d = -1.15$ [-1.19, -1.11]). Age range for competitors was 14-82 years (Males: 14-82; mean [SD], 28 [10]; Females 14-77; 29 [11]) and bodyweight ranged from 52.1-195kg (89.5 [18.3]) and 43.3-160kg (69.6 [15.7]) for males and females respectively.

Squat weight

Absolute and relative first SQ attempt weights (regardless of [lift attempt](#) success) are shown in Figure 1. Mean absolute first SQ attempt weight (regardless of [lift attempt](#) success) was 7.0kg greater ($P<0.001$, $d=0.14$ [0.10, 0.18]) in those who won compared to non-winners [when analysing all competitors together](#). These observations were similar in females (10.6kg, $P<0.001$, $d=0.44$ [0.38, 0.50]) and males (16.7kg, $P<0.001$, $d=0.41$ [0.36, 0.46]) that won compared to non-winners.

<<Insert Figure 1 about here>>

Absolute weight difference between SQ attempts are shown in Table 1. [For all competitors](#), those who won had a greater absolute increase in SQ attempt weight between the first and second lift attempt compared to non-winners (0.5kg, $P<0.001$, $d=0.10$ [0.06, 0.14]), which corresponded to a 2.1% (OR 95%CI: 1.013, 1.030; $P<0.001$) increased odds of winning for each kilogram of weight increase between attempt one and two. On average, male winners increased by 0.9kg, ($P<0.001$, $d=0.19$ [0.14, 0.24]) more than non-winners and female winners increased by 0.7kg ($P<0.001$, $d=0.23$ [0.16, 0.29]) more than non-winners between the first and second SQ attempt. This corresponded to a 3.9% (OR 95%CI: 1.029, 1.050; $P<0.001$) and a 7.8% (OR 95%CI: 1.056, 1.101; $P<0.001$) increased odds of winning per additional kilogram, respectively.

<<Insert Table 1 about here>>

The absolute weight difference ($\Delta 0.6$ kg, $P<0.001$, $d=0.08$ [0.04, 0.12]) between SQ attempt one was greater in winners compared to non-winners for [all competitors](#), which corresponded to a 1.2% increased (OR 95%CI: 1.006, 1.017; $P<0.001$) odds of winning per additional kilogram ([Table 4](#)). When dichotomised by sex, the difference in weight between attempt one and three was greater in males who won compared to non-winners ($\Delta 1.5$ kg,

$P < 0.001$, $d = 0.20$ [0.15, 0.25]) and females ($\Delta 0.9\text{kg}$; $P < 0.001$, $d = 0.20$ [0.14, 0.26]). In males, this corresponded with 2.8% increased (OR 95%CI: 1.021, 1.036; $P < 0.001$) odds of winning per additional kilogram. In females, this corresponded with 2.8% increased (OR 95%CI: 1.006, 1.050; $P = 0.013$) odds of winning per additional kilogram.

The percentage of competitors who successfully lifted their chosen SQ weight at attempt one, two, and three, respectively, is shown in Table 2. **For all competitors**, those who won had a greater percentage of successful SQs at attempt one, two and three. This was also true for all attempts for males but only at attempt one and three for females. The largest OR for success is seen at attempt one for males (OR 1.20, 95%CI 1.00, 1.43), females (OR 1.50, 95%CI 1.21, 1.85) and **across all competitors** (OR 1.30, 95%CI 1.14, 1.49). The percentage of competitors achieving their maximum successful SQ weight for the competition (i.e.CM) at each attempt is shown in Table 3. **For all competitors**, 66% of athletes achieved their heaviest successful SQ at attempt three. The percentage of athletes who won and achieved their heaviest successful SQ at attempt three was significantly different to non-winners **for all competitors** ($P < 0.001$), as well as for males ($P = 0.011$) and females ($P < 0.001$). Additionally, Table 4 shows the percentage of the CM attempted for each SQ across all athletes within each sex and weight class, as well as for winners compared to non-winners. **For all competitors**, there was no difference between winners and non-winners in the percentage of CM at attempt one or two. The percentage of CM for attempt three was greater for non-winners (101.87%) than those who won (101.69%, $P < 0.01$; i.e. non-winners attempted a greater proportion of their maximum at attempt three but were less likely to successfully lift this amount).

<<Insert Tables 2-4 about here>>

DISCUSSION

Despite a growing body of PL research, the impact of intra-competition factors on competition success [has been poorly](#) explored. Given the theorised importance of the SQ in particular, the aim of this study was to investigate the effects of absolute and relative opening SQ attempts, the weight increase between SQ attempts, success rate of each attempt (percentage) and attempt that the maximum SQ occurred at, and the subsequent effect on the odds of winning a PL competition. Collectively, the results suggest that both male and female PL athletes with greater opening SQ attempts (absolute and relative to body weight) have an increased probability of winning. Additionally, a greater weight increase between an athletes' first and second, and second and third SQ attempt also increased their probability of winning. [Additionally, athletes should prioritise successful completion of all three squat attempts in order to enhance their odds of competitive success.](#) Importantly, the data presented in this study can be used by coaches and athletes to optimise intra-competition strategies to facilitate desirable competition outcomes.

Our results indicate that the likely winner of a PL competition can be identified based on the opening SQ attempt. Specifically, the absolute value was for the most part (all but the 59kg, 62kg and 69kg male weight classes), higher in eventual winners than non-winners. Additionally, those who won typically had greater (absolute) increases in weight between attempt one and two (mean[SD]; all competitors: 9.5[4.9]kg vs 9.0[4.7]kg, males: 11.2[5.2]kg vs 10.3[4.8]kg, females: 7.2[3.2]kg vs 6.5[3.0]kg) and attempt two to three (mean[SD]; all competitors: 6.5[4.2]kg vs 6.3[4.0]kg, males: 7.8[4.6]kg vs 7.2[4.3]kg, females: 4.9[2.9]kg vs 4.6[2.9]kg) for the SQ. This is important as the greater increase between attempts further separates winners from non-winners in each subsequent attempt. Interestingly, greater SQ one repetition maximum (1RM) performance is also associated with greater BP 1RM performance

¹⁹. Thus, competitors who perform well in the SQ are also more likely to perform well in the BP and, therefore, likely to go on to achieve greater competition totals. Consequently, the SQ is arguably a pivotal discipline within the sport of PL. However, despite differences in SQ weight between winners and non-winners it is possible, that over time, less strong athletes may be able to overcome this difference. For example, Latella et al. ⁹ reported that male PL athletes in the lowest starting strength quartile gained strength more quickly than males in the highest starting strength quartile, suggesting a greater rate of performance improvement can be achieved. That being said, in the same study ⁹, there were no differences in strength gain per day between weaker and stronger female PL athletes. However, this does not mean that less strong females, or moderately strong males are unable to overcome the strength differential between themselves and their stronger counterparts. Rather than solely focussing on strength development, these females, and potentially males, may also need to consider focussing their efforts on other performance enhancing factors such as favourable body composition changes.

Our results demonstrate that more non-winners than winners achieved their CM at the second attempt (26.29% vs 28.33%) while more winners achieved their CM on the third (67.25% vs 63.25%) attempt compared to non-winners. Moreover, Table 4 shows that the percentage of CM attempted in the third SQ was lower for winners compared to non-winners. Combined, these results suggest that winners are more likely to appropriately strategize to perform better on successive SQ attempts and to select a third attempt weight that is more likely to be successful. Moreover, these findings indicate that a conservative and cumulative approach may be feasible to facilitate PL SQ performance during competition and this is likely a result of appropriate planning and strategy. [The successful completion of all three SQ attempts appears to be an important factor contributing to competitive success.](#)

The greatest increase in OR for winning was seen with a successful lift at the first attempt. Thus, the first SQ attempt likely presents as an important opportunity to improve the odds of competitive success. This is consistent with previous evidence in other contexts (e.g. basketball, volleyball and fencing) suggesting success of early attempts is predictive of favourable outcomes in subsequent performance^{13-16,20,21}. In support, our findings suggest that the ability of an athlete and coach to select attempt weight is important, athletes need to have a successful lift attempt and they need to open at approximately 92% of their predicted CM for their first SQ. This requires technical precision to perform the lift, and an optimal level of arousal to perform at their best^{22,23}. However, competitive anxiety must be controlled in order to achieve competitive success^{23,24}. Research shows that exposure to competition specific environments during training (I.e. judging of attempts, competitor tactics and time restrictions between attempts) using affective and representative learning designs have been implemented with success²⁵. These designs promote the use of training strategies which replicate the demands of competition²⁶ and the implementation of such methods has shown success in other sports we suggest that this should also be considered in PL²⁷⁻³⁰. In PL practice, this could specifically include judging of lift attempts in accordance with competition standards, practice of attempt weight selections prior to real competition and mock competition with fellow athletes during training. To the best of our knowledge, no research has provided empirical evidence to athletes or coaches about optimal openers for the SQ in PL. Based on our findings, athletes and coaches appear to select an opening attempt weight which is approximately 92% of their CM, and success rates of these opening SQ attempts do not differ between those who won and lost. However, those who won are more likely to achieve a successful second and third lift, affording greater opportunities to increase attempt weights and to enhance their odds of winning. Whilst it is important for coaches and athletes to limit competitive anxiety while maintaining positive arousal, our results suggest that the strength of the athlete may be more

important, or perhaps attenuate the effects of competitive anxiety based on the relative attempt weight and successful outcome of the lift being similar for winners and non-winners. It is important for coaches and athletes to understand the athlete's predicted CM. In order to better predict an athlete's CM on the day of competition, practical approaches providing instantaneous feedback during the warm-up for example, may prove advantageous if allowed within the rules of each competition ^{31,32}. One possibility is the measurement of movement velocity (via various wireless or tethered devices) during increasing warm-up lifts to better predict the likely CM for an individual athlete at any given competition.

Furthermore, the success rate of each SQ attempt was only higher in winner and non-winners in a handful of categories specifically, but overall, was different for all males, all females and when analysing all competitors-(refer to Table 2). This overall result is also in-line with reports from previous research ¹¹. In particular, Pritchard and Morton ¹¹, showed that athletes who won had a greater percentage of successful first lifts (across all lift disciplines) compared to non-winners. This finding was also evident in the current analysis of SQ outcomes, but this difference also extended to the second and third attempt. This difference may, at least in part, also occur due to the psychological influence of prior unsuccessful attempts although we acknowledge that psychological factors could not be specifically explored in this analysis. Additionally, Pritchard and Morton ¹¹ also reported that the percentage of successful lifts on any attempt declines significantly from the first to the second, and then to the third attempt ¹¹. A decrease in attempt success was also observed across SQ attempt one to three. Specifically, this averaged 90.2%, 84.6% and 66.1% for SQ attempt one, two and three, respectively, for all competitors. Notably, this rate decreased by ~23% for winners and ~25% for non-winners by the third attempt. This decline could be due to many factors including the physiological effects of fatigue with repeated attempts. Nonetheless, the

findings further highlight the importance of the first, and subsequent SQ attempts during PL competition.

PRACTICAL APPLICATIONS

This study provides detailed and novel information for coaches and athletes regarding PL competition strategy and specifically highlights the importance of the SQ in competition outcomes. To optimise odds of competitive success, athletes should select an opening SQ attempt that is approximately 92% of perceived or calculated CM, allowing them to successively increase each attempt weight with the aim to successfully complete all three attempts. Moreover, coaches and athletes should use the collective information presented in this paper during the preparation phase and competition itself to plan for and strategize opening and subsequent attempt selection on an individual athlete basis. Specifically, coaches should also consider the use of competition day methods to predict CM. For example, Table 1 provides evidenced based information for suggested weight increases between attempts based on athlete sex and weight class. Together, these data can be used to formulate and modify competitive strategy to improve the odds of competitive success. In addition to training strategies to improve maximum strength, coaches and athletes should also consider specific practice of competitive scenarios to reduce performance anxiety and to expose athletes to judging of attempts in-line with competition standards.

CONFLICT OF INTEREST

All Authors declare that they have no conflicts of interest to disclose.

AUTHOR CONTRIBUTIONS

Robert Howells, Jemima Spathis, Patrick Owen and Daniel van den Hoek contributed to study design, data management, manuscript development and revision.

Patrick Owen and Christopher Latella contributed to project design, statistical analysis, manuscript development and revision.

Joel Garrett and Joshua Pearson contributed to manuscript development , revision and formatting.

All authors have read and approved the final version of this manuscript.

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Table 1. Average absolute increase between squat (SQ) attempts (regardless of attempt outcome) of those who won and lost in IPF and WP sanctioned competitions.

Weight class	Increase between attempt 1 & 2 (kg)		Increase between attempt 2 & 3 (kg)	
	Won	Lost	Won	Lost
Female (all)	7.2 (3.2)‡	6.5 (3.0)	4.9 (4.2)*	4.6 (2.9)
47kg[^]	5.75 (2.33)	5.24 (2.08)	4.02 (2.71)	3.93 (2.45)
48kg[#]	5.00 (1.70)	6.19 (1.77)	3.47 (2.08)	4.50 (0.76)
52kg[^]	6.15 (2.42)*	5.38 (2.55)	3.82 (2.55)	3.32 (2.78)
53kg[#]	6.39 (2.57)	5.21 (3.11)	3.90 (2.28)	2.69 (2.64)
57kg[^]	6.50 (2.75)*	5.89 (2.58)	3.97 (2.53)	4.25 (2.59)
58kg[#]	6.15 (2.98)	5.98 (2.55)	4.12 (2.88)	3.60 (2.42)
63kg[^]	6.75 (2.76)†	6.07 (2.65)	4.63 (2.70)	4.31 (2.66)
64kg[#]	7.21 (2.48)	6.60 (2.43)	4.54 (1.83)	4.37 (2.00)
72kg^{#^}	7.55 (3.04)‡	6.78 (2.92)	5.12 (2.70)*	4.76 (2.69)
84kg^{#^}	7.79 (3.00)‡	6.80 (3.36)	5.29 (2.77)	5.01 (2.99)
84kg^{+^}	8.18 (4.40)*	7.32 (3.86)	6.26 (3.46)	5.97 (3.93)
100kg[#]	8.80 (2.95)*	7.24 (3.57)	5.24 (3.59)	5.25 (2.73)
100kg^{+#}	8.23 (3.87)	7.17 (3.40)	6.09 (2.91)	7.70 (2.74)
Male (all)	11.2(5.2)	10.3 (4.8)	7.8 (4.6)‡	7.2 (4.3)
59kg[^]	8.16 (3.78)	8.40 (7.12)	5.58 (3.76)	6.83 (5.49)
62kg[#]	7.30 (3.18)	7.67 (3.38)	7.74 (4.78)	3.63 (5.99)
66kg[^]	9.33 (4.18)	9.11 (3.58)	6.47 (3.84)	6.23 (4.62)
69kg[#]	10.11 (3.32)	9.05 (3.94)	7.01 (2.98)	5.85 (2.73)
74kg[^]	9.48 (3.96)	9.54 (5.59)	6.74 (4.06)*	6.10 (3.85)
77kg[#]	9.26 (4.53)	9.70 (3.58)	6.43 (3.61)	6.95 (3.12)
83kg[^]	10.69 (4.28)‡	9.65 (4.25)	6.84 (3.52)	6.76 (4.01)
85kg[#]	10.51 (3.51)	10.18 (3.39)	6.91 (3.83)	6.94 (3.32)
93kg[^]	11.66 (4.91)‡	10.26 (4.20)	7.81 (4.66)	7.56 (4.05)
94kg[#]	12.13 (4.17)†	10.44 (4.25)	8.15 (3.70)	7.48 (3.76)
105kg^{#^}	12.04 (5.66)†	11.00 (4.76)	8.71 (4.55)‡	7.70 (4.13)
120kg^{#^}	13.01 (6.31)†	11.29 (5.68)	8.88 (4.71)	8.45 (5.45)
120kg^{+#^}	14.44 (6.17)	13.97 (7.58)	10.89 (6.52)	9.60 (6.07)
All competitors	9.5 (4.9)‡	9.0 (4.7)	6.5 (4.2)	6.3 (4.0)

Data are mean (standard deviation). * P<0.05, † P<0.01, ‡ P<0.001 when compared to lost.

World Powerlifting (WP), ^ International Powerlifting Federation (IPF)

Table 2. Percentage of successful squat (SQ) attempts between those who won and lost in IPF and WP sanctioned competitions.

Group	SQ Attempt 1 (% successful)				SQ Attempt 2 (% successful)				SQ Attempt 3 (%successful)			
	All	Won	Non-Winners	OR	All	Won	Non-Winners	OR	All	Won	Non-Winners	OR
Female (all)	89.91	91.85‡	88.28	1.50 (1.21, 1.85)‡	83.38	84.46	82.47	1.16 (0.98, 1.37)	65.57	68.33†	63.26	1.25 (1.10, 1.43)†
47kg[^]	93.02	92.31	95.24	0.60 (0.07, 5.45)	80.23	80.00	80.95	0.94 (0.27, 3.28)	46.51	44.62	52.38	0.73 (0.27, 1.96)
48kg[#]	87.50	87.50	87.50	1.00 (0.08, 13.02)	91.67	87.50	100.00	NA	75.00	75.00	75.00	1.00 (0.14, 7.10)
52kg[^]	88.93	93.96†	81.73	3.48 (1.50, 8.04)†	77.08	83.22 †	68.27	2.31 (1.27, 4.18)†	55.73	55.70	55.77	1.00 (0.60, 1.65)
53kg[#]	92.19	97.50*	83.33	7.80 (0.82, 74.50)	81.25	92.50 †	62.50	7.40 (1.76, 31.16)†	62.50	70.00	50.00	2.33 (0.82, 6.65)
57kg[^]	90.00	92.34	87.23	1.76 (0.92, 3.40)	80.24	79.28	81.38	0.88 (0.54, 1.43)	60.49	64.86*	55.32	1.49 (1.00, 2.22)*
58kg[#]	88.72	87.04	89.87	0.76 (0.26, 2.23)	81.20	77.78	83.54	0.69 (0.29, 1.65)	60.90	68.52	55.70	1.73 (0.84, 3.58)
63kg[^]	91.59	93.46	90.36	1.53 (0.84, 2.77)	80.12	81.54	79.19	1.16 (0.78, 1.73)	58.87	65.00*	54.82	1.53 (1.11, 2.11)*
64kg[#]	94.84	97.14	93.71	2.28 (0.48, 10.86)	91.55	94.29	90.21	1.79 (0.57, 5.66)	78.40	80.00	77.62	1.15 (0.57, 2.33)
72kg^{#^}	90.78	93.04	89.56	1.56 (0.97, 2.51)	86.27	86.91	85.93	1.09 (0.75, 1.58)	64.71	63.23	65.51	0.91 (0.69, 1.18)
84kg^{#^}	89.41	90.73	88.22	1.31 (0.79, 2.16)	85.17	87.54	83.05	1.43 (0.93, 2.22)	72.16	77.96†	66.95	1.75 (1.23, 2.47)†
84kg^{+^}	83.67	86.30	80.45	1.53 (0.90, 2.61)	81.91	84.47	78.77	1.47 (0.88, 2.45)	71.86	76.26*	66.48	1.62 (1.04, 2.51)*
100kg[#]	93.75	100.00*	86.84	NA	82.50	80.95	84.21	0.80 (0.25, 2.55)	82.50	80.95	84.21	0.80 (0.25, 2.55)
100kg^{+#}	78.72	81.25	73.33	1.58 (0.37, 6.71)	89.36	84.38	100.00	NA	89.36	87.50	93.33	0.50 (0.05, 4.90)
Male (all)	90.42	91.39*	89.87	1.20 (1.00, 1.43)*	85.35	86.68*	84.61	1.18 (1.02, 1.37)*	66.41	68.91†	65.01	1.19 (1.07, 1.33)†
59kg[^]	88.03	93.40†	72.22	5.44 (1.89, 15.67)†	80.28	81.13	77.78	1.23 (0.49, 3.10)	52.11	55.66	41.67	1.76 (0.82, 3.78)

62kg[#]	83.33	95.00[†]	25.00	57.00 (2.76, 1176.76)[†]	87.50	100.00[‡]	25.00	NA	83.33	95.00[†]	25.00	57.00 (2.76, 1176.76)[†]
66kg[^]	90.88	89.82	92.25	0.74 (0.33, 1.68)	81.42	84.43	77.52	1.57 (0.87, 2.83)	62.50	65.27	58.91	1.31 (0.82, 2.10)
69kg[#]	90.63	95.83	85.42	3.93 (0.77, 19.98)	87.50	87.50	87.50	1.00 (0.30, 3.35)	67.71	68.75	66.67	1.10 (0.47, 2.59)
74kg[^]	90.16	89.01	90.73	0.83 (0.52, 1.32)	80.44	81.56	79.90	1.11 (0.77, 1.60)	60.89	64.54	59.09	1.26 (0.94, 1.69)
77kg[#]	89.64	86.57	91.27	0.62 (0.24, 1.57)	89.64	85.07	92.06	0.49 (0.19, 1.25)	73.58	71.64	74.60	0.86 (0.44, 1.67)
83kg[^]	90.29	91.24	89.94	1.16 (0.75, 1.81)	83.61	86.40	82.57	1.34 (0.94, 1.92)	66.39	69.79	65.14	1.24 (0.94, 1.62)
85kg[#]	89.81	87.14	91.18	0.66 (0.26, 1.64)	85.44	81.43	87.50	0.63 (0.28, 1.38)	75.73	75.71	75.74	1.00 (0.51, 1.96)
93kg[^]	90.55	92.67	89.82	1.43 (0.91, 2.26)	86.87	86.22	87.10	0.93 (0.65, 1.33)	63.39	62.76	63.61	0.96 (0.75, 1.24)
94kg[#]	90.53	95.77	88.37	2.98 (0.86, 10.38)	92.18	91.55	92.44	0.89 (0.32, 2.43)	73.66	76.06	72.67	1.19 (0.63, 2.27)
105kg^{#^}	91.44	91.47	91.42	1.01 (0.64, 1.58)	86.39	88.53	85.21	1.34 (0.91, 1.96)	69.93	74.40*	67.46	1.40 (1.06, 1.86)*
120kg^{#^}	88.36	90.03	86.75	1.38 (0.83, 2.29)	88.20	89.35	87.09	1.24 (0.75, 2.05)	70.83	72.51	69.21	1.17 (0.82, 1.67)
120kg+^{#^}	93.18	95.24	90.54	2.09 (0.88, 4.97)	87.24	92.06[†]	81.08	2.71 (1.39, 5.28)[†]	66.47	70.37	61.49	1.49 (0.94, 2.34)
All competitors	90.22	91.59[‡]	89.33	1.30 (1.14, 1.49)[‡]	84.60	85.71*	83.88	1.15 (1.03, 1.29)*	66.09	68.66[‡]	64.41	1.21 (1.11, 1.31)[‡]

Data are percent of successful lifts within group or odds ratio (OR; 95% confidence interval) of winning. * P<0.05, † P<0.01, ‡ P<0.001 when compared to non-winners. # World Powerlifting (WP), ^ International Powerlifting Federation (IPF). NA: OR not available due to complete separation

Table 3. Percent of competitors that reach their squat (SQ) competition maximum (CM) at each attempt.

Group	SQ Attempt 1			SQ Attempt 2			SQ Attempt 3		
	All (%)	Winners (%)	Non-winners (%)	All (%)	Winners (%)	Non-winners (%)	All (%)	Winners (%)	Non-winners (%)
Female (all)	6.63	6.68	6.58	26.84	25.37	28.07	65.03	67.95	62.58
47kg[^]	10.47	12.31	4.76	43.02	43.08	42.86	46.51	44.62	52.38
48kg[#]	4.17	6.25	0.00	20.83	18.75	25.00	75.00	75.00	75.00
52kg[^]	6.32	4.70	8.65	35.57	39.60	29.81	55.73	55.70	55.77
53kg[#]	7.81	2.50*	16.67	26.56	27.50	25.00	62.50	70.00	50.00
57kg[^]	9.51	11.71	6.91	29.27	23.42†	36.17	60.00	64.86	54.26
58kg[#]	8.27	12.96	5.06	29.32	20.37	35.44	59.40	66.67	54.43
63kg[^]	8.87	8.46	9.14	30.58	26.54	33.25	58.87	65.00	54.82
64kg[#]	2.82	1.43	3.50	18.31	18.57	18.18	77.93	80.00	76.92
72kg^{#^}	6.18	7.24	5.60	28.73	29.81	28.14	64.22	62.95	64.90
84kg^{#^}	6.05	4.47	7.47	21.48	18.53	24.14	71.26	77.00	66.09
84kg^{+^}	4.27	3.65	5.03	22.11	20.55	24.02	70.60	75.80	64.25
100kg[#]	3.75	4.76	2.63	12.50	16.67	7.89	81.25	78.57	84.21
100kg^{+#}	0.00	0.00	0.00	10.64	12.50	6.67	89.36	87.50	93.33
Male (all)	6.57	6.28	6.73	27.95	27.01	28.47	64.71	66.71*	63.60
59kg[^]	11.27	14.15	2.78	35.21	33.02	41.67	50.00	52.83	41.67
62kg[#]	0.00	0.00	0.00	12.50	10.00	25.00	79.17	90.00†	25.00
66kg[^]	8.45	7.19	10.08	30.41	29.34	31.78	60.81	63.47	57.36
69kg[#]	6.25	6.25	6.25	26.04	25.00	27.08	67.71	68.75	66.67
74kg[^]	9.37	8.87	9.62	30.09	28.37	30.94	59.48	62.77	57.87
77kg[#]	2.59	2.99	2.38	25.39	25.37	25.40	72.02	71.64	72.22
83kg[^]	7.18	5.14	7.93	27.00	25.98	27.37	65.25	68.88	63.91
85kg[#]	5.83	7.14	5.15	18.45	17.14	19.12	74.76	75.71	74.26

93kg[^]	6.30	7.62	5.85	31.06	30.79	31.15	62.04	61.58	62.20
94kg[#]	3.29	4.23	2.91	25.51	21.13	27.33	71.19	74.65	69.77
105kg^{#^}	5.71	5.60	5.77	25.59	23.20	26.92	67.75	71.20	65.83
120kg^{#^}	4.38	4.12	4.64	26.81	28.52	25.17	67.96	67.35	68.54
120kg+^{#^}	6.82	3.70*	10.81	28.49	28.57	28.38	64.09	67.72	59.46
All competitors	6.59	6.45	6.68	27.53	26.29*	28.33	64.83	67.25‡	63.25

* P<0.05, † P<0.01, ‡ P<0.001 when compared to non-winners. # World Powerlifting (WP), ^ International Powerlifting Federation (IPF).

Table 4. Percent of squat (SQ) competition maximum (CM) data between those who won and lost in IPF and WP sanctioned competitions.

Group	SQ Attempt 1 (%CM)				SQ Attempt 2 (%CM)				SQ Attempt 3 (%CM)			
	All	Winners	Non-Winners	OR	All	Winners	Non-Winners	OR	All	Winners	Non-Winners	OR
Female (all)	91.21 (4.78)	91.27 (4.79)	91.16 (4.77)	1.005 (0.992, 1.018)	97.52 (3.95)	97.53 (3.93)	97.50 (3.97)	1.002 (0.986, 1.018)	101.96 (3.32)	101.80 (3.20)	102.10 (3.42)†	0.973 (0.955, 0.992)†
47kg[^]	91.91 (4.38)	92.00 (4.78)	91.62 (2.90)	1.021 (0.911, 1.144)	98.79 (4.14)	98.87 (4.46)	98.53 (3.01)	1.021 (0.904, 1.153)	103.72 (4.44)	103.76 (4.49)	103.58 (4.38)	1.009 (0.901, 1.130)
48kg[#]	91.47 (4.08)	92.12 (4.10)	90.17 (3.97)	1.137 (0.903, 1.431)	97.27 (3.04)	97.57 (3.37)	96.66 (2.31)	1.121 (0.815, 1.541)	101.25 (2.30)	101.22 (2.30)	101.32 (2.44)	0.981 (0.675, 1.426)
52kg[^]	92.08 (4.53)	92.03 (4.14)	92.15 (5.09)	0.994 (0.939, 1.052)	98.38 (3.61)	98.33 (3.36)	98.45 (3.97)	0.991 (0.923, 1.063)	102.22 (3.07)	102.18 (2.88)	102.27 (3.35)	0.991 (0.912, 1.077)
53kg[#]	91.61 (5.37)	90.32 (5.36)†	93.97 (4.62)	0.850 (0.746, 0.968)*	97.91 (3.83)	96.88 (3.25)†	99.79 (4.16)	0.788 (0.658, 0.943)†	101.57 (2.67)	100.88 (1.46)†	102.83 (3.78)	0.739 (0.580, 0.943)*
57kg[^]	91.79 (4.76)	92.01 (4.71)	91.53 (4.82)	1.021 (0.980, 1.064)	98.12 (4.29)	98.29 (4.23)	97.90 (4.36)	1.021 (0.975, 1.070)	102.39 (3.68)	102.21 (3.70)	102.62 (3.66)	0.970 (0.920, 1.024)
58kg[#]	91.97 (4.63)	92.47 (5.19)	91.62 (4.18)	1.042 (0.964, 1.126)	98.04 (3.92)	98.10 (4.56)	98.00 (3.43)	1.006 (0.920, 1.101)	101.91 (3.10)	102.04 (3.64)	101.82 (2.66)	1.024 (0.914, 1.147)
63kg[^]	91.78 (4.72)	91.68 (4.72)	91.84 (4.73)	0.993 (0.960, 1.026)	97.94 (4.19)	97.76 (4.07)	98.06 (4.26)	0.982 (0.946, 1.020)	102.35 (3.40)	101.98 (3.20)†	102.61 (3.51)	0.945 (0.900, 0.992)*
64kg[#]	90.57 (3.99)	90.65 (3.92)	90.53 (4.04)	1.008 (0.938, 1.083)	96.87 (2.82)	96.82 (2.74)	96.89 (2.87)	0.991 (0.894, 1.097)	101.03 (2.30)	100.81 (1.82)	90.57 (3.99)	0.935 (0.816, 1.071)
72kg^{#^}	91.14 (4.61)	91.54 (4.48)*	90.92 (4.67)	1.030 (1.001, 1.060)*	97.52 (3.86)	97.81 (3.99)	97.36 (3.78)	1.030 (0.996, 1.065)	102.00 (3.29)	102.10 (3.40)	101.94 (3.23)	1.015 (0.977, 1.055)
84kg^{#^}	90.82 (4.74)	90.63 (4.46)	91.00 (4.98)	0.983 (0.952, 1.016)	97.05 (3.89)	96.87 (3.59)	97.21 (4.16)	0.978 (0.940, 1.018)	101.58 (3.05)	101.16 (2.50)‡	101.96 (3.44)	0.913 (0.864, 0.964)†

84kg⁺ [^]	90.16 (5.79)	90.07 (6.07)	90.29 (5.41)	0.993 (0.959, 1.029)	96.62 (4.08)	96.46 (4.02)	96.82 (4.16)	0.979 (0.931, 1.029)	101.80 (3.72)	101.49 (3.16)	102.22 (4.33)	0.949 (0.897, 1.003)
100kg[#]	90.21 (4.27)	90.63 (4.22)	89.71 (4.34)	1.053 (0.946, 1.172)	96.78 (3.74)	97.28 (3.93)	96.19 (3.49)	1.089 (0.952, 1.244)	101.01 (2.67)	101.11 (2.61)	100.90 (2.78)	1.031 (0.869, 1.223)
100kg⁺ #	89.81 (3.68)	90.24 (3.99)	88.89 (2.81)	1.110 (0.931, 1.324)	95.71 (2.76)	96.26 (2.82)*	94.54 (2.28)	1.290 (0.983, 1.694)	100.81 (2.92)	100.92 (3.21)	100.58 (2.25)	1.048 (0.821, 1.338)
Male (all)	92.04 (4.43)	92.09 (4.14)	92.01 (4.59)	1.004 (0.992, 1.015)	97.69 (3.58)	97.69 (3.63)	97.69 (3.55)	1.001 (0.987, 1.015)	101.69 (3.03)	101.60 (3.11)	101.75 (2.98)	0.983 (0.966, 1.000)
59kg[^]	92.20 (4.80)	92.57 (4.52)	90.94 (5.55)	1.073 (0.987, 1.167)	98.14 (4.75)	98.49 (4.72)	96.96 (4.76)	1.075 (0.982, 1.177)	102.58 (3.52)	102.51 (3.47)	102.82 (3.76)	0.975 (0.873, 1.090)
62kg[#]	87.35 (6.37)	86.63 (6.23)	94.53 (0.37)	NA	94.12 (5.20)	93.61 (5.18)	99.18 (1.16)	0.439 (0.148, 1.302)	100.54 (1.70)	100.32 (1.39)	102.60 (3.68)	0.626 (0.343, 1.142)
66kg[^]	91.81 (4.98)	91.78 (4.64)	91.84 (5.42)	0.998 (0.952, 1.045)	97.85 (3.99)	97.79 (3.86)	97.93 (4.17)	0.991 (0.935, 1.050)	102.06 (3.15)	101.99 (3.26)	102.14 (3.01)	0.984 (0.915, 1.060)
69kg[#]	91.03 (4.42)	90.37 (4.74)	91.69 (4.01)	0.932 (0.848, 1.025)	97.20 (3.48)	97.04 (3.64)	97.36 (3.34)	0.973 (0.867, 1.093)	101.58 (2.71)	101.86 (3.12)	101.30 (2.23)	1.083 (0.929, 1.261)
74kg[^]	92.43 (5.09)	92.71 (4.18)	92.29 (5.48)	1.017 (0.987, 1.047)	98.13 (3.84)	98.03 (3.69)	98.19 (3.92)	0.989 (0.953, 1.027)	101.93 (2.89)	101.78 (2.81)	102.01 (2.93)	0.972 (0.924, 1.024)
77kg[#]	91.82 (3.58)	92.44 (3.52)	91.49 (3.58)	1.077 (0.990, 1.172)	97.19 (2.63)	97.48 (2.79)	97.03 (2.53)	1.067 (0.952, 1.196)	101.17 (2.20)	101.19 (2.09)	101.15 (2.27)	1.008 (0.881, 1.154)
83kg[^]	92.35 (4.11)	92.55 (3.61)	92.28 (4.28)	1.016 (0.985, 1.048)	97.87 (3.41)	97.87 (2.87)	97.86 (3.59)	1.001 (0.964, 1.038)	101.72 (2.92)	101.38 (2.52)*	101.85 (3.05)	0.940 (0.896, 0.987)*
85kg[#]	91.46 (3.94)	91.77 (3.87)	91.29 (3.98)	1.031 (0.958, 1.110)	97.18 (3.09)	97.52 (3.26)	97.00 (2.99)	1.055 (0.961, 1.158)	101.02 (2.19)	101.12 (2.54)	100.97 (1.99)	1.031 (0.906, 1.174)
93kg[^]	92.31 (4.03)	92.64 (3.90)	92.19 (4.08)	1.028 (0.997, 1.060)	97.79 (3.37)	98.14 (3.75)*	97.67 (3.22)	1.041 (1.004, 1.079)*	101.79 (3.20)	101.89 (4.23)	101.75 (2.76)	1.013 (0.976, 1.051)

94kg[#]	91.72 (3.68)	91.51 (3.31)	91.81 (3.83)	0.978 (0.908, 1.055)	97.26 (2.88)	97.14 (2.92)	97.31 (2.87)	0.979 (0.889, 1.079)	101.19 (2.35)	101.03 (2.00)	101.26 (2.48)	0.955 (0.841, 1.085)
105kg[#] [^]	91.94 (4.30)	91.93 (4.22)	91.94 (4.34)	0.999 (0.970, 1.029)	97.57 (3.75)	97.49 (3.97)	97.62 (3.61)	0.991 (0.957, 1.025)	101.50 (2.94)	101.30 (2.92)	101.61 (2.95)	0.962 (0.918, 1.009)
120kg[#] [^]	91.46 (4.85)	91.75 (4.07)	91.19 (5.50)	1.024 (0.990, 1.060)	97.27 (3.43)	97.51 (3.23)	97.03 (3.61)	1.042 (0.993, 1.093)	101.49 (3.17)	101.41 (2.68)	101.55 (3.57)	0.986 (0.936, 1.039)
120kg+ ^{#^}	91.62 (4.91)	91.40 (4.06)	91.91 (5.83)	0.979 (0.936, 1.024)	97.57 (3.94)	97.20 (3.59)	98.05 (4.32)	0.945 (0.893, 1.001)	102.08 (3.87)	101.76 (3.49)	102.49 (4.29)	0.952 (0.898, 1.009)
All												
competitors	91.72 (4.58)	91.73 (4.45)	91.72 (4.67)	1.000 (0.992, 1.009)	97.62 (3.73)	97.62 (3.77)	97.62 (3.70)	1.000 (0.989, 1.010)	101.80 (3.15)	101.69 (3.15)†	101.87 (3.14)	0.982 (0.969, 0.994)*

Data are mean (standard deviation) percent of squat (SQ) competition maximum (CM) and odds ratio (OR; 95% confidence interval) of winning. *

P<0.05, † P<0.01, ‡ P<0.001 when compared to non-winners. # World Powerlifting (WP), ^ International Powerlifting Federation (IPF). NA: OR not available due to complete separation.

Figure captions:

Figure 1. Average absolute (A-B) and relative (C-D) first squat (SQ) attempt (regardless of attempt outcome) of those who won and lost in IPF and WP sanctioned competitions Data are mean (standard deviation). * $P < 0.05$, † $P < 0.01$, ‡ $P < 0.001$ when compared to lost.