Predicting a Successful Attempt in Raw Powerlifting. A Nonlinear Mixed Logistic Regression Analysis

Ian A. J. Darragh,[1] Brendan Egan,[2,3] David Nolan,[2] and Kathleen E. Bennett[1,4]

[1]School of Population Health, RCSI University of Medicine and Health Sciences Dublin, Ireland; [2]School of Health and Human Performance, Dublin City University, Dublin, Ireland; [3]Florida Institute for Human & Machine Cognition, Pensacola, Florida; and [4]Beaumont RCSI Cancer Centre, Dublin, Ireland

Abstract

Darragh, IAJ, Egan, B, Nolan, D, and Bennett, KE. Predicting a successful attempt in raw powerlifting. A nonlinear mixed logistic regression analysis. *J Strength Cond Res* XX(X): 000–000, 2025—This study aimed to predict successful lift attempts in raw powerlifting by examining the influence of jump size (the absolute difference in weight between consecutive attempts) and other factors, using a logistic regression model with nonlinear splines. Data from 93,333 lifters (62,679 males, 30,654 females) across 6,979 International Powerlifting Federation competitions were analyzed. The data set was partitioned into training (80%) and test (20%) sets, with sex-specific models developed to account for class imbalance. Predictors included jump size, lift type (squat, bench press, deadlift), attempt transition (first-to-second or second-to-third), and covariates such as body mass, age, and opening attempt weight. Random effects for lifter identity were included to control for individual performance variability. Significance was set at $p < 0.05$. Results revealed that jump size significantly influenced success rates, with effects varying by lift type, attempt transition, and sex. For male lifters, moderate jump sizes (5–20 kg) improved squat and deadlift success, but success declined with jumps >20 kg, especially on third attempts. Bench press success increased slightly with jump sizes <10 kg but dropped sharply beyond that—more so in third attempts. For female lifters, squat success improved only with small jumps (≤8 kg); jumps >10 kg significantly reduced success, particularly on third attempts. In the bench press, female lifters showed an almost linear decline in success with increasing jump size on second attempts, with third-attempt success decreasing sharply beyond 4 kg. Female deadlift success followed a similar pattern to squats but showed slightly greater tolerance, with optimal jumps approximately 9–11 kg. In both sexes, third attempts consistently had lower success rates than second attempts. These findings highlight the nuanced role of jump size in attempt success and provide actionable insights for competition strategy. Coaches and lifters can use these results to optimize attempt selection, particularly in balancing risk and reward across attempts.

Key Words: strength training, competition performance, weight selection, performance prediction, lift success

Introduction

Powerlifting is a sport that consists of 3 lifting events: the squat, bench press, and deadlift. In a full powerlifting competition, subjects are afforded 3 attempts at each lift with the heaviest successful attempt for each lift being combined to provide a combined score (known as a *total*). Most commonly the total score is used to determine competition placing, except in circumstances when determining best overall lifter, or tied totals within a class where coefficients or body weight has an influence on placing (4). Powerlifting competitions are organized by numerous federations, although the fundamental rule for competition success is always consistent (i.e., highest total achieved wins). The principal rule differences between powerlifting federations often concern the required range of motion that must be achieved for a lift to be successful (e.g., the depth required on a squat) (21); the extent to which ancillary equipment is permitted (e.g., the characteristics of "protective" equipment such as belts, wrist wraps, and knee sleeves or allowances for performance-enhancing equipment such as knee wraps, bench shirts, or single/multiply suits) (16); and the presence or absence of testing for performance-enhancing drugs (e.g., anabolic steroids) (8), all of which may influence how much a competitor can lift.

Raw (sometimes termed "classic") powerlifting places strict restrictions on assistive equipment based on the idea that minimally assisted lifting performances are almost entirely determined by an individual's physiologic capacity for neuromuscular strength (4,21). The International Powerlifting Federation (IPF) is the largest global federation for raw powerlifting and uses a strict emphasis on judging procedures, assistive equipment characteristics, and antidoping controls (4,6). Previous studies have attempted to examine factors that underlie powerlifting performance using IPF competition data (3,9,17–19). Two of these studies aimed to identify factors that predict performance using frequency-based methods of between-group comparison (9,17), or difference-based models with odds ratios (OR) to predict competition placing (18,19). Only 1 study has previously used predictive modeling, with the aim of determining which factors may predict overall competition performance (3).

To date, no study has used predictive modeling to determine factors that influence a successful outcome of an individual lift

Address correspondence to Ian A. J. Darragh, iandarragh1@gmail.com.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (http://journals.lww.com/nsca-jscr).

Journal of Strength and Conditioning Research 00(00)/1–9

attempt. In addition, no study has yet examined the influence of jump size (the absolute difference in weight to be lifted between 2 consecutive attempts) on any aspect of powerlifting performance. This analysis is potentially impactful because jump size could be an influential factor for a successful lift, and being directly manipulatable by a lifter or coach during a powerlifting competition. Therefore, the aim of this study was to use a large repository of IPF raw powerlifting data to build a predictive model that can provide insight into how jump size influences the probability of a successful lift attempt within a powerlifting competition.

Methods

Experimental Approach to the Problem

Data were acquired from the OpenPowerlifting database on August 24, 2024 (13). Because the IPF federation emphasizes strict competition standards and attempts stringent antidoping protocols (6), only data from IPF-sanctioned competitions were analyzed. Data were cleaned appropriately to calculate jump size and build nonlinear mixed logistic regression models that can predict the influence of jump size on a successful lift outcome. Main effects such as lift and attempt transition and covariates such as body mass, age, and opening attempt weight were also included in models based on inclusion improving model fit (see below).

Subjects

Subjects were male (n = 62,693) and female (n = 30,655) powerlifters who had their records logged on the OpenPowerlifting database. The mean age of male lifters was 27.6 (*SD* = 11.4, range: 7 - 82) years and the mean body mass was 88.3 kilograms (kg) (*SD* = 19.2). The mean age of female lifters was 29.5 (*SD* = 11.7, range: 7 - 96) years and the mean body mass was 68.7 kg (*SD* = 16.3). The information from the OpenPowerlifting database is available for free in the public domain, therefore, ethical approval was not required for this study. The data analysed in the study met the criteria for a research ethics exemption based on the criteria outlined by the research ethics committee at Dublin City University.

Data Preparation

All data cleaning and modeling were performed using the R programming language (version 4.4.2) (15). Data were filtered as follows: only events that were sanctioned by the IPF and used the "full" meet format (i.e., subjects must complete at least 1 attempt of each of the squat, bench press, and deadlift to register a total) were considered; within events, only subjects who had values for age and body mass recorded, and who registered 9 full attempts (3 squats, 3 bench press, and 3 deadlifts) were included. Subjects who were guest lifters (lifters who performed at the competition, but whose performances were not ranked in the competition standings), disqualified for rule violations, or disqualified for doping violations were removed. The primary predictor of interest was "jump size" (defined here as the absolute value in kilograms (kg) between 2 successive attempts of the same lift). Jump size was calculated by subtracting the absolute value (in kg) of each lift attempt in a consecutive order (squat attempt 1 load—squat attempt 2 load, squat attempt 2—squat attempt 3, etc). Data were filtered so only circumstances where subjects successfully completed their first attempt of each lift were kept because it is impossible to determine the "jump" between the subject's last warm-up attempt and first competition attempt. This choice was not expected to bias models because a successful first attempt (for either squat, bench press, or deadlift) does not alter the probability of successful second or third attempts (3). During a preliminary manual screening of data, approximately 81 additional individuals were removed because of having reported attempt jump sizes that were deemed to be clerical errors due to their unrealistic nature (e.g., a 47 kg female lifter who had a deadlift jump of 500 kg) (see Table 5, Supplemental Digital Content, http://links.lww.com/JSCR/A695). The final filtered data set consisted of data from 93,333 lifters (62,679 male, 30,654 female) from 140 countries across 6,979 distinct competitions spanning a period 33.8 years (September 1990—August 2024).

Statistical Analyses

Before model development, data were split randomly into "training" sets (consisting of 80% of sex-partitioned data: male training set, n = 50,037; female training set, n = 24,492) and a test set (consisting of 20% of sex-partitioned data: male test set, n = 12,642; female test set, n = 6,162) to enable internal validation of the model's predictive power. The final data set contained information from 1,366,646 individual attempts (male attempts = 876,337, female attempts = 490,309). Before data were partitioned into training and test subsets, descriptive differences in the success rates between different lifts (squat, bench, and deadlift), and the success rates between- and within-sexes were assessed using chi-squared tests. All models were constructed on sex-partitioned training data and models were internally validated with appropriate test data (see "Internal model validation"). To predict the influence of jump size on lift outcome, nonlinear mixed effects logistic regression models with 2 degrees of freedom were built using the "glmmTMB" and "splines" packages built for the R programming language (2). Owing to class imbalance for sex (62% of the data being male), independent models were produced for male and female lifters, respectively (12). Initially, basic logistic regression models were constructed with lift success as dependent variable, and univariate predictive factors examined (i.e., jump size), and then other main effects (e.g., lift) and covariates (e.g., age, body mass) being iteratively included in the model. The value of adding new variables was assessed by examining whether the addition of a new variable resulted in reductions in Akaike Information Criteria (AIC) and residual deviances. After main effects were identified, interactions between main effects were investigated with the value of interactions similarly being assessed through changes in residual deviance. After all interactions were identified, the random effect of the individual lifter was included (random intercept). Models were generated using both absolute values (i.e., jump size in kilograms) and relative values (jump size as a percentage change from the previous attempt). The models containing absolute values are presented in the main text of the article, but the model outputs and figures for relative values are available within the supplementary material (see Tables 3 and 4, Supplemental Digital Content, http://links.lww.com/JSCR/A695 respectively, with appropriate figures also provided).

The equation of the final model formula for both male and female models based on absolute values is presented as follows:

$$Logit(P(Lift\ Outcome = Successful)) = \beta_0 + S1(\text{jump size, lift, attempt transition}) + \beta 1(\text{age}) + \beta 2(\text{body mass}) + \beta 3(\text{first attempt weight}) + u_{Individual\ Lifter},$$

where β_0 is the intercept. S1 represents the nonlinear interaction between jump size (the change in load between attempts in kg), lift (whether the lift was squat, bench press, or deadlift), and attempt transition (whether the transition was between the first to second attempt or second to third attempt). Additional covariates were age (the age of the lifter in years); body mass (the body mass of the lifter in kg); and first attempt load (the value of each lifter's opening attempt in kg). The sole random effect u represents the random effect associated with the individual lifter. The final model ran with a maximum number of 40,000 evaluations and 20,000 iterations and used maximum likelihood estimation to enhance convergence. All models used nonlinear minimization with bounds for convergence (20). Akaike Information Criteria and Bayesian Information Criteria (BIC) were automatically generated for each model. The intraclass correlation coefficient (ICC) for the random effect of lifter identity for models was estimated by dividing the random effect variance by the sum variance of the model. Odds ratios are reported alongside model terms as a standardized measure of effect size. These can be used to interpret the extent to which different terms influence the probability of a successful lift outcome, for example, if a term has an OR of 2.0, this implies the term increases the probability of a successful attempt by 100%. Further information on the interpretation of ORs can be found elsewhere (1).

Internal Model Validation

Internal validation was performed for both male and female models using sex-specific test data that models had not previously been exposed to and that corresponded to 20% of the sample size for each respective sex (12,501 male lifters and 6,166 female lifters). Receiver operating characteristic curves were generated to examine the relationship between model sensitivity (the model's ability to predict a successful lift outcome) and specificity (the model's ability to predict a failed lift outcome). The "optimal" sensitivity threshold for a balanced model was estimated by Youden's index and the distance to ideal point methods, with various thresholds above or below this number subsequently being estimated to optimize model prediction (see Figure 1, Supplemental Digital Content, http://links.lww.com/JSCR/A695). The best performance thresholds were determined to be 0.65 for the male model and 0.60 for the female model. Models were evaluated based on sensitivity, specificity, accuracy, positive predictive value, and Cohen's kappa coefficient. The relevant data and code used to produce and validate predicted models are openly available on the open science framework alongside other supplementary materials at the following link—https://osf.io/37h6t/?view_only=b9d299771a1044ee89dc9c00c98e17e0.

Results

Descriptive Information

The demographic information for male and female lifters are shown in Figure 1. The distribution of the jump sizes and absolute values for each lift partitioned by sex is shown in Figure 2. The proportional difference in success rates between lifts (irrespective of attempt) is shown in Figure 3. The overall success rate for male lifters on the squat was 77% (second attempt = 87%, third attempt = 68%) with overall success rate of 75.3% (second attempt = 84%, third attempt = 65%) for female lifters. The average success rate for male lifters on the bench press was 66% (second attempt = 82%, third attempt = 49%) with 63.2% (second attempt = 81%, third attempt = 45%) for female lifters. The average success rate for male lifters on the deadlift was 74.4% (second attempt = 88%, third attempt = 59%) with 79% (second attempt = 91%, third attempt = 66%) for female lifters. For both sexes, the success rate of bench press was significantly lower than squat and deadlift ($p < 0.01$). The success rate of squat was significantly greater than the success rate of deadlift for male lifters ($p < 0.01$), and the success rate of deadlift was significantly greater than success rate of squat for female lifters ($p < 0.01$). Male lifters demonstrated a higher percentage of success for squat and bench press attempts (both $p < 0.01$), while female lifters demonstrated a higher percentage of success for deadlift attempts ($p < 0.01$). Significant differences were observed in the relative (% change between 2 consecutive attempts) jump size between male lifters and female lifters for first–second (6.6% for male lifters, 7.5% for female lifters, $p < 0.01$) and second–third attempt transition (4.2% for male lifters, 4.8% for female lifters, $p < 0.01$) (see Table 5, Supplemental Digital Content, http://links.lww.com/JSCR/A695).

Male Predictive Model

The full model outputs for the male model are presented in Supplemental Digital Content (see Table 1, http://links.lww.com/JSCR/A695). Nonlinear effects of jump size and their interactions are modeled using natural splines (df = 2) and are shown in Figure 4 (for interactions) and Figure 5 (for covariates). The random effect of lifter identity had a variance of 0.44 ($SD = 0.66$) and an ICC of 12%. Significant main effects were observed for lift (reference category: squat; bench press—$\beta = -0.30$, OR = 0.74, $SE = 0.05$, $p < 0.01$; deadlift—$\beta = 0.47$, OR = 1.60, $SE = 0.07$, $p < 0.01$), and attempt transition reference: first-to-second attempt; $\beta = -0.86$, OR = 0.42, $SE = 0.05$, $p < 0.01$). Significant main effects were estimated for body mass ($\beta = 0.015$, OR = 1.02, $SE = 0.0003$, $p < 0.01$) and first attempt weight ($\beta = -0.0098$, OR = 0.99, $SE = 0.0001$, $p < 0.01$). Spline-transformed jump size terms were significant (spline 1: $\beta = 0.77$, $SE = 0.10$, $p < 0.01$; spline 2: $\beta = -3.09$, $SE = 0.20$, $p < 0.01$). Two-way interactions were estimated between jump size and lift (e.g., spline 1 × bench press $\beta = -2.03$, $p < 0.01$; spline 2 × deadlift: $\beta = 0.61$, $p = 0.01$), and between jump size and attempt transition (spline 1: $\beta = -1.54$, $p < 0.01$; spline 2: $\beta = -1.88$, $p < 0.01$). A significant interaction was also estimated between lift and attempt transition (bench press: $\beta = -0.88$, OR = 0.41, $SE = 0.06$, $p < 0.01$; deadlift: $\beta = -0.78$, OR = 0.46, $SE = 0.07$, $p < 0.01$). Significant 3-way interactions were estimated between jump size, lift, and attempt transition for bench press (e.g., spline 1: $\beta = -3.68$, $p < 0.01$; spline 2: $\beta = -8.70$, $p < 0.01$), and deadlift (spline 2: $\beta = -1.68$, $p < 0.01$).

Female Predictive Model

The full model outputs for the female model are presented in Supplemental Digital Content (see Table 2, http://links.lww.com/JSCR/A695). Nonlinear effects of jump size and their interactions are modeled using natural splines (df = 2) and shown in Figure 4 (for interaction effects) and Figure 5 (for covariates). The random effect of lifter identity had a variance of 0.39 ($SD = 0.63$) and an ICC of 11%. Significant main effects were estimated for lift

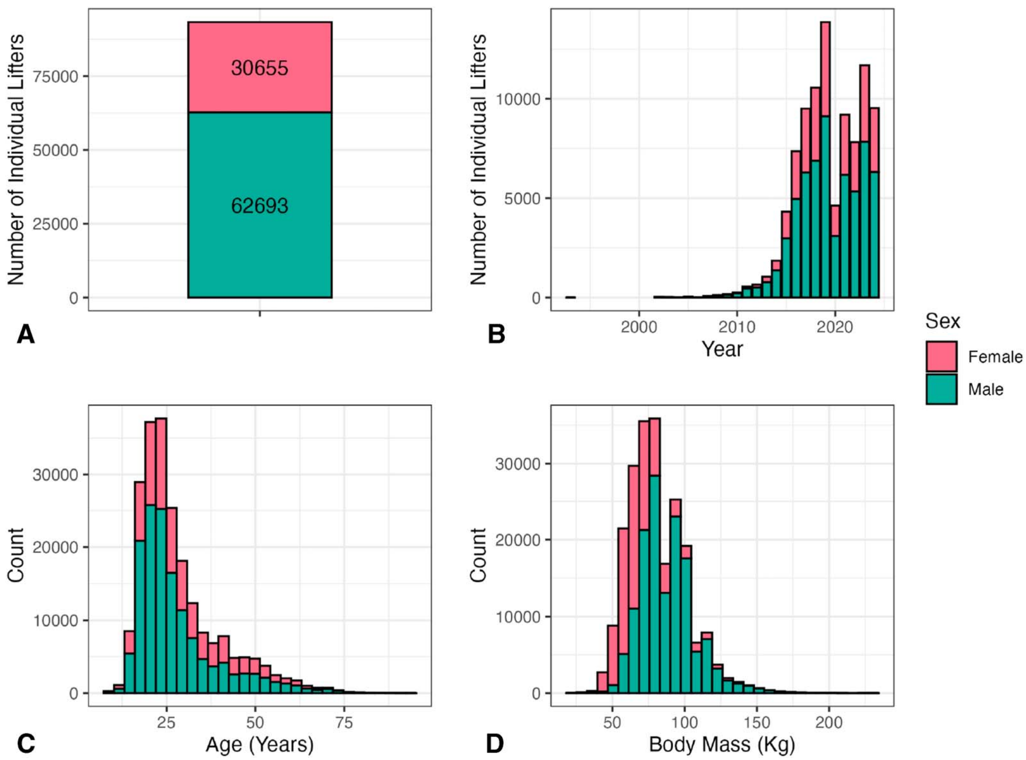

Figure 1. The descriptive information of lifters within the data set. (A) The proportion of male and female lifters in the data. (B) The number of individuals lifters who competed in raw IPF powerlifting competitions by year and sex. (C) The age distribution of lifters in the data. (D) The body mass distribution of lifters in the data.

(reference category: squat; bench press—$\beta = -0.21$, OR = 0.81, $SE = 0.07$, $p < 0.01$; deadlift—$\beta = 0.67$, OR = 1.95, $SE = 0.08$, $p < 0.01$), and attempt transition (reference: first-to-second attempt; $\beta = -1.12$, OR = 0.33, $SE = 0.06$, $p < 0.01$). Significant main effects were estimated for body mass ($\beta = 0.016$, OR = 1.02, $SE = 0.0004$, $p < 0.01$), first attempt load ($\beta = -0.011$, OR = 0.99, $SE = 0.0002$, $p < 0.01$), and age ($\beta = -0.001$, OR = 0.99, $SE = 0.0006$, $p = 0.04$). Spline-transformed jump size terms were both significant (spline 1: $\beta = -1.84$, $SE = 0.20$, $p < 0.01$; spline 2: $\beta = -5.88$, $SE = 0.57$, $p < 0.01$). Significant 2-way interactions were estimated for jump size and lift (bench spline 1: $\beta = -2.27$, $p < 0.01$; deadlift spline 1: $\beta = 1.41$, $p < 0.01$), and between jump size and attempt transition (spline 1: $\beta = -1.45$, $p < 0.01$; spline 2: $\beta = -3.27$, $p < 0.01$). A significant interaction was also estimated between lift and attempt transition (bench press: $\beta = -1.03$, OR = 0.36, $SE = 0.07$, $p < 0.01$; deadlift: $\beta = -0.64$, OR = 0.53, $SE = 0.09$, $p < 0.01$). Significant 3-way interactions between jump size, lift, and attempt transition were observed for bench press (e.g., spline 1: $\beta = -16.55$, $p < 0.01$; spline 2: $\beta = -35.78$, $p < 0.01$) and for deadlift (spline 1: $\beta = -1.99$, $p < 0.01$; spline 2: $\beta = -4.85$, $p < 0.01$).

Validation of the Male Model

The full results of internal validation for the male model are presented in Supplemental Digital Content (see Table 1, http://links.lww.com/JSCR/A695). The male model demonstrated a sensitivity of 87% with a kappa of 0.28, and a positive predictive value of 79%. The male model had a specificity of 39% and negative predictive value of 52%. The male model demonstrated a balanced accuracy of 63%.

Validation of the Female Model

The full results of internal validation for the female model are presented in Supplemental Digital Content (see Table 2, http://links.lww.com/JSCR/A695). The female model had a sensitivity of 88% with a kappa of 0.27, and a positive predictive value of 79%. The female model had a specificity of 36% and negative predictive value of 53%. The female model demonstrated a balanced accuracy of 62%.

Discussion

This study aimed to build predictive models capable of providing insight into factor(s) that influence a successful attempt in raw powerlifting competition(s), and, in particular, the extent to which jump size between 2 consecutive lifts influences the probability of a successful lift outcome. This study is novel, because it uses nonlinear predictive modeling on an unexamined aspect of powerlifting performance—the probability of a successful attempt. Although other studies have endeavored to explore factors that influence competitive powerlifting performance (3,9,17–19), only 1 study has previously used a form of predictive modeling (multilevel modeling) (3). The primary strengths of this study are that it uses a population level sample size (multiple performances from 93,333 distinct lifters), and the malleable nature of the primary predictor (jump size) means that results of the model can be used to inform competition strategy. In both male and female predictive models, jump size was established as a factor that influences the probability of a successful lift attempt for all 3 lifts (discussed subsequently). In addition, both models estimated a negative main effect of second to third attempt transition for all 3 lifts. In other words, it was observed that, irrespective of any

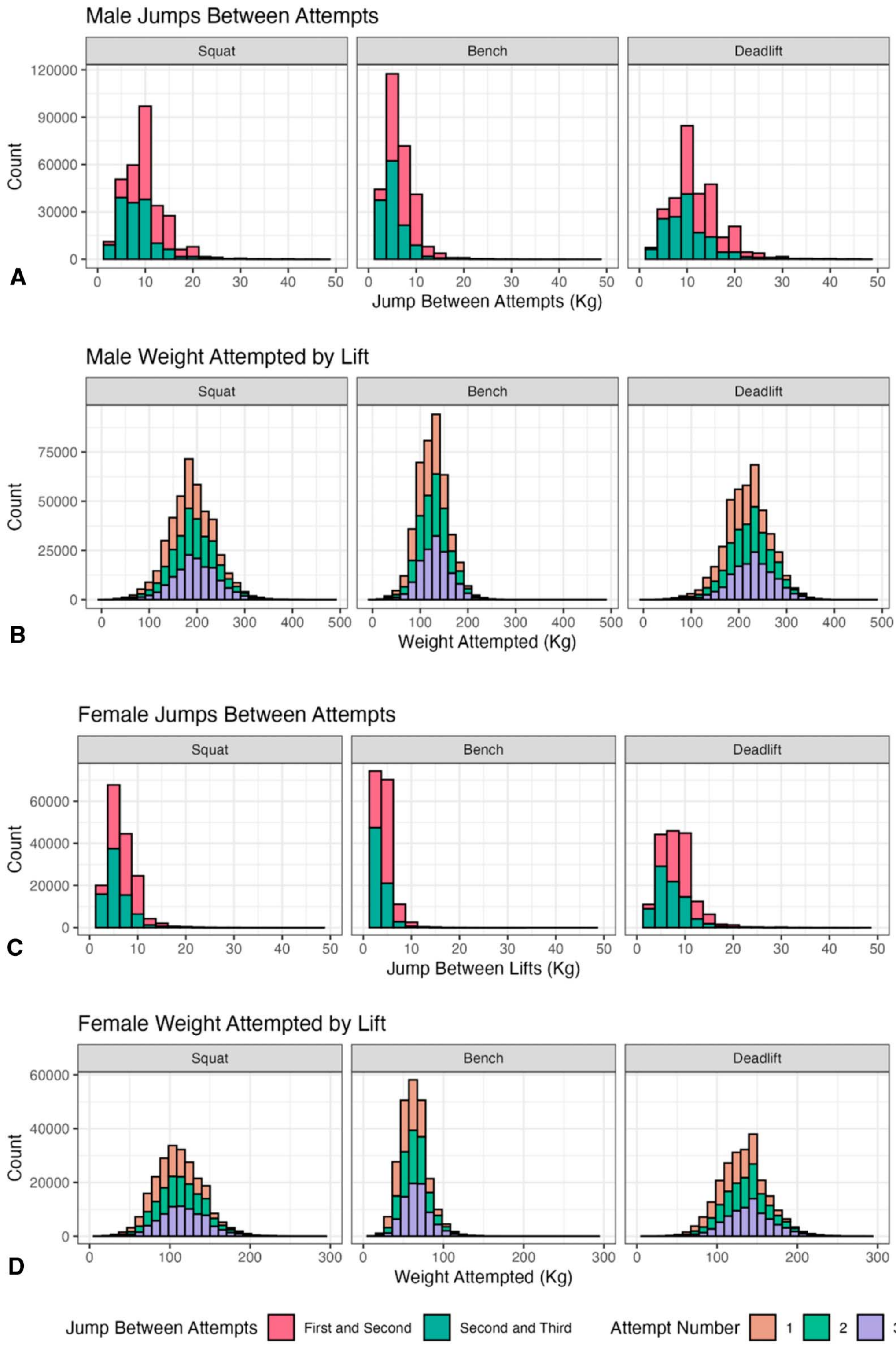

Figure 2. The performance characteristics of male and female lifters. (A) Distribution of jump size for male lifters. (B) Distribution of attempt weights by lift for male lifters. (C) Distribution of jump size for female lifters. (D) Distribution of attempt weights by lift for female lifters.

other factors, the probability of making a successful third attempt was always lower than the probability of making a successful second attempt. This finding is consistent with a previous study that examined lifters (111 males, 33 females) competing in the 2012 and 2013 Oceania and classic IPF world championships, which identified that the probability of any lift being successful declined by ~17% from the first to second attempt and declined by ~32% from the second to third attempt (14).

The bench press demonstrated the lowest success rate for both sexes (66% males and 63% females), while the lift with the

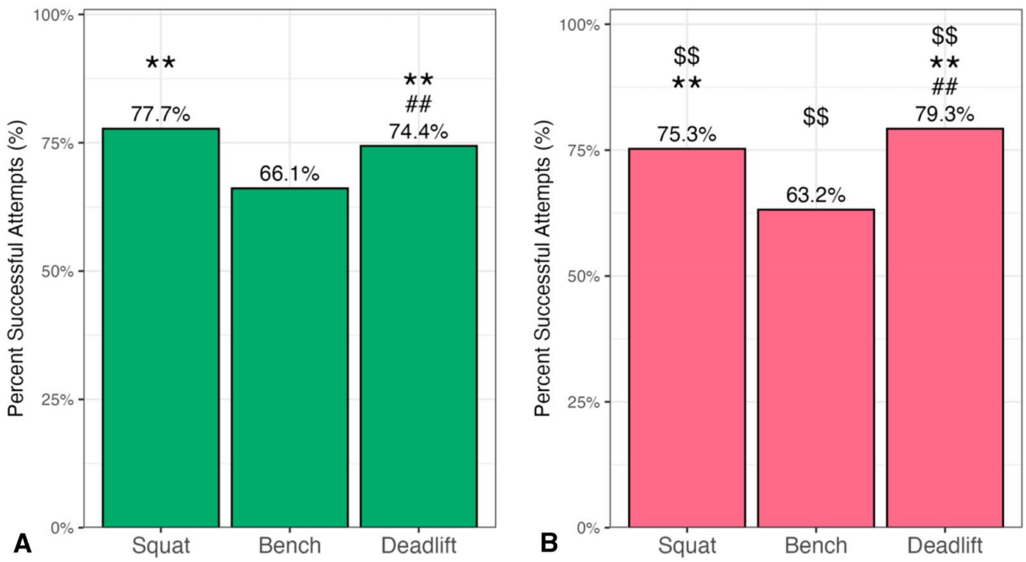

Figure 3. The overall success rates for each lift portioned by sex. (A) Male lifters. (B) Female lifters. *Represents a significant difference in success rate from bench press (*$p < 0.05$, **$p < 0.01$). #Represents a significant difference in success rate from squat (#$p < 0.05$, ##$p < 0.01$). $Represents a significant difference in success rate between female and male lifters ($ $p < 0.05$, $$ $p < 0.01$).

highest success rate for male lifters was the squat (77%) and deadlift for female lifters (79%). Differences were observed in the success rates of each lift between attempts, although these tended to be small. In general, male lifters demonstrated higher success rates for the squat (2.4% greater than female lifters) and bench press (2.9% greater than female lifters), while female lifters had a higher success rate for deadlift (4.9% greater than male lifters).

With respect to the influence of jump size on each individual lift, a notable finding in this study is that, irrespective of other variable, jump sizes of up to 15 kg increase the probability of squat success for male lifters, with the probability of squat success increasing ~7.5% between jumps of 5–20 kg. However, for male lifters, the probability of a successful attempt also subsequently decreases with jumps >20 kg (i.e., probability of squat success decreases ~2% between jump sizes of 15–20 kg). In contrast, for female lifters, only jump sizes up to 8 kg positively influenced squat success and jumps within this range had smaller beneficial effects than for male lifters (i.e., squat success increases from ~2.5% between jumps of 5–8 kg). In addition, jump sizes of >10 kg reduced the probability of squat success for female lifters with larger magnitude compared with that for male lifters (i.e., squat success decreases ~6.5% between jumps of 10–15 kg for female lifters). However, that the nature of the relationship between jump size and squat success is modified when the interaction with attempt transition is considered (i.e., whether a squat occurs as a second attempt, or third attempt). First, the maximum value for which jump size has a positive influence on squat success is estimated to be marginally different between second and third attempts (male lifters, 15–12 kg for second and third attempts, respectively; female lifters, 10–8 kg second and third attempts, respectively). Second, the significant difference in both splines between attempts indicates that there is a larger reduction in squat success when a jump size is larger than the maximum value associated with positive influence on a successful lift. Collectively, these results indicate that for the squat lift, male lifters demonstrate a greater tolerance for larger jump sizes, and across a reasonable range (i.e., ~1–20 kg) male lifters may benefit somewhat from taking larger jumps between attempts. In contrast, female lifters demonstrate a lower tolerance for larger jump sizes and can in some circumstances see a larger detriment to success by selecting larger jump sizes than male lifters. However, the results of the interaction between jump size and attempt transition indicate that the range of jump size values that provide an increase in squat success narrows between second and third attempts. This observation may be related to the generation of fatigue, or lifters approximating closer to (or exceeding) their 1 repetition maximum values in third attempts (17). However, from a practical standpoint, the pattern is notable because it suggests that lifters may need to take smaller jumps between the second and third squat attempts to maximize the probability of squat success.

Regarding bench press, the male model similarly indicated that for both second and third attempts, increasing jump size increased the probability of bench press success. However, the range of jump size values that increased the probability of bench press success was considerably narrower (i.e., only included values < 10 kg for both attempts), and jump sizes larger than ~10 kg reduced bench press success, particularly for third attempts. This means that generally for male lifters, very small increases in jump size up to 10 kg have a minor increase on bench press success (e.g., <5% for jumps between 5 and 10 kg), while jump size >10 kg will decrease bench press success (e.g., for jumps between 10 and 15 kg, bench press success rates will decline ~4% decrease on second attempts and ~8% decrease on third attempts). For female lifters, a negative and almost linear relationship was estimated between jump size and bench press success rate on second attempts. Whereas on a third attempt, a small range of jump size values increased bench press success (e.g., ~1–4 kg) after which larger jump size rapidly decreased bench press success rates (e.g., bench press success rate declines ~10% between 4 and 10 kg jumps in third attempts). In this circumstance, it is useful to consider absolute vs. relative jump size may create a confounding effect on results. In this study, female lifters generally have larger relative (%) jump sizes than male lifters (8.4 vs. 6.5% for second attempts; 4.8 vs. 3.7% for third attempts) for bench press (see Table 7, Supplemental Digital

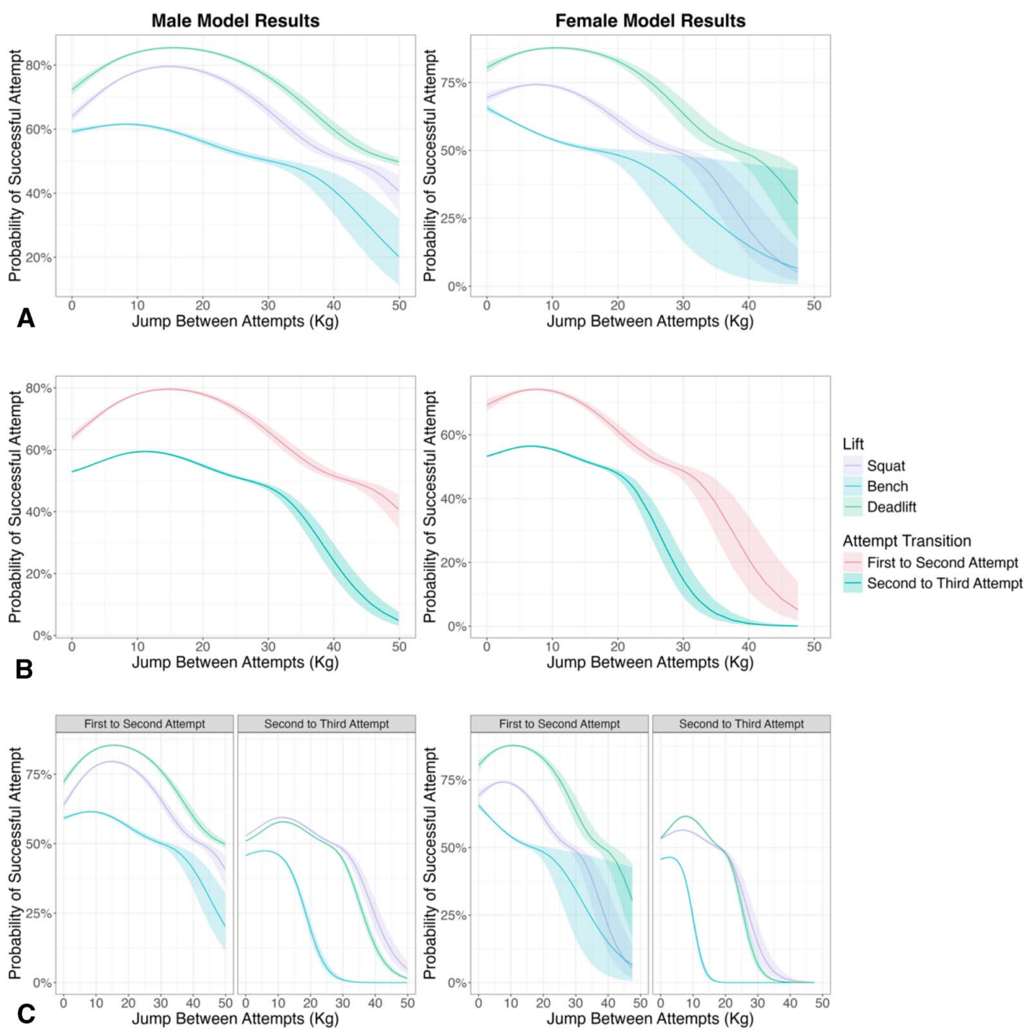

Figure 4. The results of interactions between jump between attempt size and significant predictors on the probability of lift attempt success for the male (left panel) and female lifters (right panel). (A) The varying effects of jump between attempt size on successful lift outcome between lifts (squat, bench, and deadlift). (B) The influence of jump between attempt size on the probability of a successful lift outcome between first-to-second and second-to-third attempt transitions. (C). The 3-way interaction between jump size and lift on the probability of a successful lift outcome across first-to-second and second-to-third attempt transitions. Data underwent logistic transformation to present the estimated influence of interacting predictors as percentage probability of a successful lift attempt. Shaded areas around lines represent changing 95% confidence intervals.

Content, http://links.lww.com/JSCR/A695). However, the general trend of how relative jump size affects bench press success rate within and between both sexes generally seems to be the same in comparison with absolute jump size (see Figure 2, Supplemental Digital Content, http://links.lww.com/JSCR/A695). Therefore, a notably lower tolerance for larger jump sizes on the bench press seems to be a consistent characteristic of female lifters. From a practical standpoint, it may be valuable for female lifters to plan for bench press performances that aim to maximize placing using conservative jump size strategies, particularly for third attempts. Reasons for the apparent difference in the relationship between jump size and bench press success between male and female lifters are challenging to explain. Untrained male lifters have previously been reported to have large (~57%) differences in upper body strength compared with female lifters (5), which may in part be related to male lifters having a larger proportion of lean tissue mass distributed to the trunk and upper body (7,10). Therefore, differences in muscle mass distribution between male and female lifters, potentially coupled with mechanical disadvantages experienced by female lifters in the bench press (11), explain the greater effect of jump size to lower the probability of bench press success in the female model.

Regarding the deadlift, results were largely similar to that of the squat. For male lifters, jump sizes increased success rates in the second attempt within similar ranges to that of the squat (i.e., ~7.5% increase in deadlift success rate between jumps of 5–20 kg). However, for third attempts, the rate at which deadlift success rates declined at jump sizes >12 kg was slightly larger. This potentially represents a capacity of male lifters to be marginally less successful with respect to pushing large jumps on a third attempt deadlift, which may simply be due to fatigue. For the female model, the general trend of how jump size influenced the probability of deadlift success rate was similar to the squat, but significant differences in terms of spline values were estimated for both second and third attempts that indicated that the peak value of jump size for improving deadlift success rate is slightly

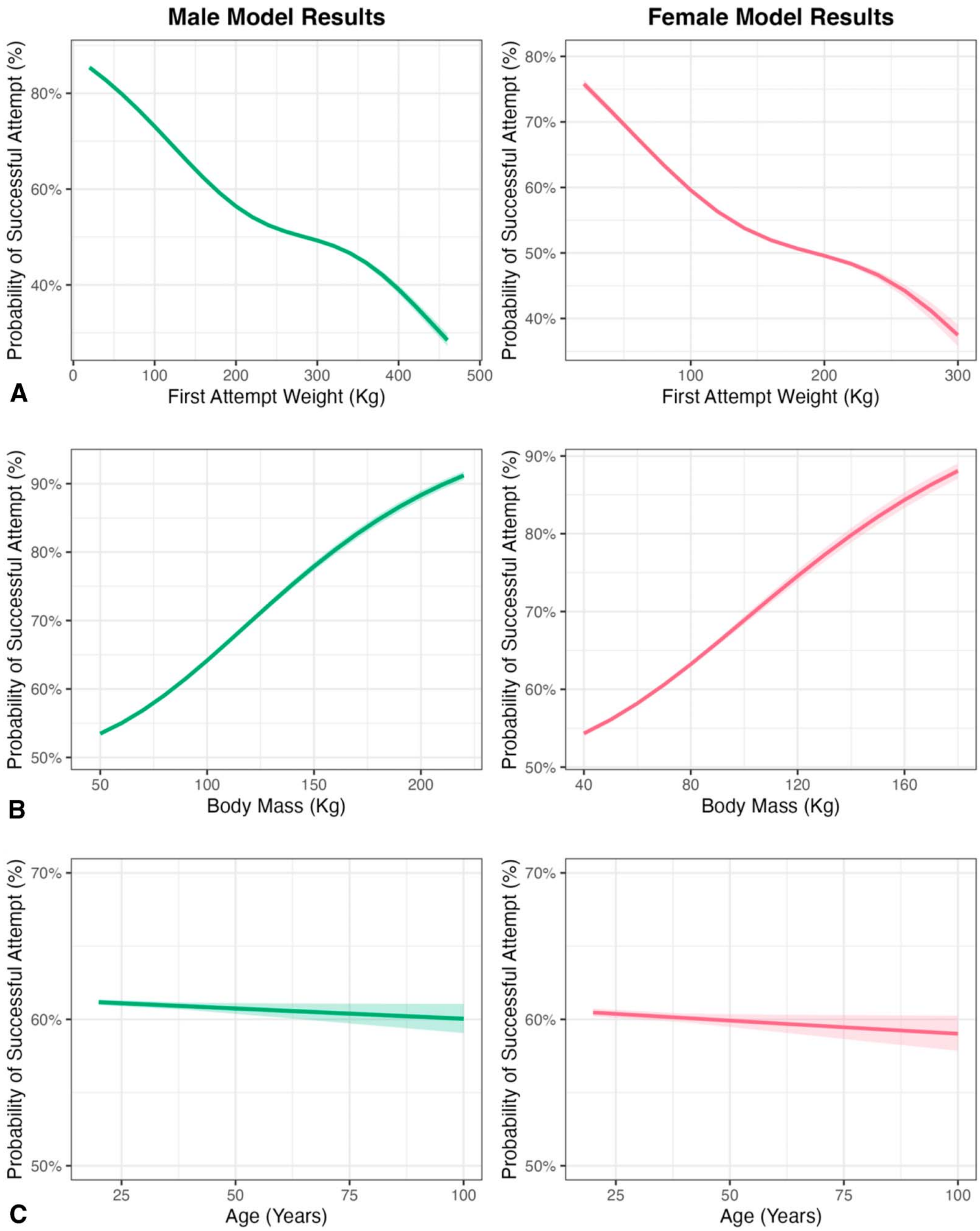

Figure 5. The influence of significant covariates on the probability of successful lift outcome (left hand panel—male model, right hand panel—female model) irrespective of attempt. (A) The influence of first attempt selection load on the probability of successful lift outcome. (B) The influence of lifter body mass on the probability of successful lift outcome. (C) The influence of lift age on the probability of successful lift outcome. Data underwent logistic transformation to present the estimated influence of interacting predictors as percentage probability of a successful lift attempt. Shaded areas around lines represent changing 95% confidence intervals.

larger in both attempts (e.g., ~11 kg for second attempts and ~9 kg for third attempts) and that the influence of jump sizes beyond the peak value on reducing the rate of deadlift success is slightly small (jumps beyond the peak value have a smaller negative influence on reducing deadlift success rates in female lifters).

Collectively, these findings demonstrate that jump size often has an influence on the probability of a successful lift outcome. This influence is nonlinear and varies depending on the lift and the attempt transition that is being considered, and the sex of the lifter competing. Despite the findings of complex interactions between the influence of jump size on individual lifts within a specific attempt transition, it is important to reiterate that a negative main effect was broadly observed for the second-to-third attempt transitions. This finding translates because the probability of a successful lift always being lower in the latter attempts of a lift, such that the absolute probability of a successful lift may still be lower in a later attempt, even if a larger jump size is predicted to have a positive effect on attempt success. However, an acknowledged limitation of this study is that it focuses on population level of insights of how jump size influences the probability of a successful lift attempt. Importantly, individual lifters may vary in their capacity to tolerate different jump sizes. Additional limitations include omitted variables such as placing or whether a lifter had coach assistance at a meet, both of which may have potential to influence a lifter's attempt strategy (e.g., making more aggressive attempt selections for overly conservative lifters, or restrained attempt selections for overly aggressive lifters). Whereas it is notable that the direct influence of coaches on powerlifting competition performance has not currently been directly studied. Although the information generated by this study does have interpretive value and practical utility, coaches must still consider the individual history and capacities of each of their competitive lifters when considering the application of these findings. In conclusion, this study provides separate models for male and female competitors that provide novel insights into how jump size influences the probability of a successful lift during a powerlifting meet, but we caution that these findings should be interpreted in their practical context.

Practical Applications

The practical applications of this study are primarily borne from the fact that we have generated robust information regarding the relationship between jump size, attempt number, sex, and the probability of a successful lift outcome. Visual inspection of this relationship enables coaches estimate the value at which a jump size may cause a lifter to see a reduction in the probability of a successful attempt. This information is useful because it can inform the planning of lifts and strategies by coaches, particularly for lifters with unfamiliar training histories. Finally, models estimated a coefficient of variation of 12–13% for the random effect of lifter identity. This value informs the final practical application of this study, which is the acknowledgment that any practical takeaways extracted from this study's predictive models will still *vary with each individual lifter*. Therefore, coaches must contextualize any practical decisions based on the results of this study to their personal understanding of their individual lifters capacities and jump size tolerances.

Acknowledgments

I. A. J. Darragh conceptualized the study, acquired the data, performed the analysis, wrote and edited the article. B. Egan contributed to the analysis and edited the article. D. Nolan contributed to the analysis and edited the article. K. E. Bennett conceptualized the study, contributed to the analysis, and edited the article.

References

1. Bland JM, Altman DG. Statistics notes. The odds ratio. *BMJ* 320: 1468, 2000.
2. Brooks ME, Kristensen K, Benthem KV, et al. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R J* 9: 378–400, 2017.
3. Coker NA, Varanoske AN, Baker KM, Hahs-Vaughn DL, Wells AJ. Predictors of competitive success of national-level powerlifters: A multilevel analysis. *Int J Perform Anal Sport* 18: 796–805, 2018.
4. Ferland P-M, Comtois AS. Classic powerlifting performance: A systematic review. *J Strength Cond Res* 33: S194–S201, 2019.
5. Hilton EN, Lundberg TR. Transgender women in the female category of sport: Perspectives on testosterone suppression and performance advantage. *Sports Med* 51: 199–214, 2021.
6. International Powerlifting Federation. International Powerlifting Federation rulebook. 2024. Available at: https://www.powerlifting.sport/fileadmin/ipf/data/rules/technical-rules/english/IPF_Technical_Rules_Book_2024_24_Jan.pdf. Accessed December 12, 2024.
7. Janssen I, Heymsfield SB, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. *J Appl Physiol* 89: 81–88, 2000.
8. Jokipalo I, Khudayarov A. A netnography and a survey on doping use among competitive doping-untested strength-sport athletes. *Int J Sports Med* 42: 645–650, 2021.
9. Latella C, Van Den Hoek D, Teo W-P. Factors affecting powerlifting performance: An analysis of age- and weight-based determinants of relative strength. *Int J Perform Anal Sport* 18: 532–544, 2018.
10. Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: Development and cross-validation of anthropometric prediction models. *Am J Clin Nutr* 72: 796–803, 2000.
11. Mausehund L, Krosshaug T. Understanding bench press biomechanics—Training expertise and sex affect lifting technique and net joint moments. *J Strength Cond Res* 37: 9–17, 2023.
12. Oommen T, Baise LG, Vogel RM. Sampling bias and class imbalance in maximum-likelihood logistic regression. *Math Geosci* 43: 99–120, 2011.
13. OpenPowerlifting. OpenPowerlifting.org. 2024.
14. Pritchard HJ, Morton RH. Powerlifting: Success and failure at the 2012 and 2013 Oceania and classic world championships. *J Aust Strength Cond* 23: 67–70, 2015.
15. R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, 2021. Available at: https://www.R-project.org/.
16. Todd J, Morais DG, Pollack B, Todd T. A historical analysis of the use of supportive apparel in powerlifting. *Iron Game Hist* 13: 37–56, 2015.
17. Travis SK, Zourdos MC, Bazyler CD. Weight selection attempts of elite classic powerlifters. *Percept Mot Skills* 128: 507–521, 2021.
18. Van Den Hoek DJ, Owen PJ, Garrett JM, et al. What are the odds? Identifying factors related to competitive success in powerlifting. *BMC Sports Sci Med Rehabil* 14: 110, 2022.
19. van den Hoek D, Garrett J, Travis SK, et al. Analysis of competition performance leading to success at the international powerlifting federation world championships between 2013 and 2019. *J Strength Cond Res* 37: e555–e562, 2023.
20. Vasdekis VGS, Vlachonikolis IG. On the difference between ML and REML estimators in the modelling of multivariate longitudinal data. *J Stat Plann Inference* 134: 194–205, 2005.
21. Warpeha J. A history of Powerlifiting the United States: 50 years after York, 2015. Available at: https://www.usaplmn.com/wp-content/uploads/2014/04/History-of-Powerlifting-Warpeha-9-4-15.pdf. Accessed December 14, 2024.