The relationship of anthropometric and physical performance characteristics on competitive success in amateur, elite, and professional rodeo athletes

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For correspondence: dustinoranchuk@gmail.com

Dustin J. Oranchuk[1,4], LeeAnne K. Gullett[1,2], Michael Kicia[1], Brandon Thome[2], Alex Game[3]

1 Acumen Health, Edmonton, Alberta, Canada
2 Canadian Professional Rodeo Sports Medicine, Calgary, Alberta, Canada
3 The University of Alberta, Faculty of Kinesiology, Edmonton, Alberta, Canada
4 Health and Rehabilitation Research Institute, Auckland University of Technology, New Zealand

ABSTRACT

Reference anthropometric and physical performance qualities can improve understanding of sporting needs and streamline preparation and rehabilitation programs. However, these data and their relationships with competitive success are absent in rodeo athletes. We hypothesized that riding performance would be most correlated with hip adductor, neck, and grip strength, while jump, RSI, and change of direction abilities would best predict bull-fighting performance. Forty-three amateur (n=9), professional (n=23), or internationally ranked (n=11) male rodeo athletes (bareback=9, bull-riders=16, saddlebronc=7, bull-fighters=11) volunteered (26.8±5.6 years). Anthropometrics included body mass, height, and body-fat percentage. Performance measures included isometric hip adduction and abduction, neck flexion and extension, handgrip strength, squat and countermovement jump heights, eccentric utilization ratio, reactive strength index (RSI), change-of-direction, bike sprints, and several pneumatic power measures. Bull-fighters were taller and heavier than bull-riders (ES=0.84-0.87, p=0.008-0.017). Bull-riders were leaner than fighters (ES=0.74, p=0.012). Fighters had greater RSI than riders (ES=0.73-1.47, p<0.001-0.030). Competitive level of rodeo riders (n=32) was correlated with age, and rodeo experience (ρ=0.37-0.43, p=0.013-0.049), bent-leg abduction (ρ=0.43, p=0.014) and straight-leg hip adduction and abduction (ρ=0.49-0.56, p<0.001-0.005) and neck flexion force (ρ=0.43, p=0.016), and rotational power (ρ=0.50, p=0.004). The competitive level of the fighters was correlated with age (ρ=0.64, p=0.036) and time-trial performance (ρ=-0.76, p=0.006). This is the first study providing normative and correlational strength and power performance data in a rodeo population. These data highlight the need for more event-specific physical preparation. Riders should focus their physical preparation on hip and neck strength and rotational power. Bull-fighters should prioritize stiffness and anaerobic power.

INTRODUCTION

Rodeo comprises several strength and power-focused events, including but not limited to calf roping, steer wrestling, team roping, barrel racing, bull-fighting, and the 'rough-stock' events of bull-, bareback- and saddlebronc-riding (28). Rodeo athletes run the gambit of body sizes and require different skills to excel in their chosen event (28). Anecdotally, riding events require special techniques and strong hip adductors, neck muscles, and handgrip to remain on the animal successfully and consistently for eight seconds (4, 28, 33). Conversely, bull-fighters need to be agile, with rapid reaction times to maintain proper position relative to the bulls to keep the riders as safe as possible.

While rodeo athletes require many physical and psychological qualities to succeed (28), hip and hand strength appear valuable to maintain position (28), with neck strength potentially vital to vestibular balance and avoiding neck strains and concussions (45). Indeed, hip adductor strains are common injuries in riders (7, 27, 38, 39). While little exists regarding hip strength in rodeo athletes, many studies have examined isometric adduction and abduction strength in hockey, soccer, and rugby athletes (12, 30, 31, 34). Additionally, neck strength has an inverse relationship with head kinematics, possibly reducing head and neck injuries (10, 17, 19). Similarly, metrics such as the reactive strength index (18), jump height, eccentric utilization ratio (25), and change of direction tests (11, 22, 35) have demonstrated beneficial relationships to performance in a wide variety of sports. However, while several logic-derived physical preparation paradigms have been proposed (4, 33, 41), the relationship between the aforementioned physical qualities with riding and bull-fighting performance is presently lacking.

While rodeo events are most popular in the central United States and Canada, the sport has rapidly grown in Australia and Brazil, and is expanding internationally. Additionally, several American universities include rodeo in their intercollegiate sports, often with scholarships on the line (29, 36). However, sports science in rodeo has not developed by a sizeable magnitude as nearly all published studies have focused on injury rates and recovery protocols (7, 27, 38, 39, 45), with the lone performance study primarily reporting metabolic and reaction time characteristics (26). Thus, publicly available normative data is hard to come by, leaving rodeo athletes and strength and conditioning professionals to utilize anecdotal reports or data from their own, likely limited pool of athletes, to guide training. Therefore, this study aimed to provide normative anthropometric and performance data across several rodeo events and highlight actionable insights regarding strength and conditioning. We hypothesized that riding performance would be most correlated with experience, and hip adductor, neck, and grip strength measures, while jump, RSI, and change of direction abilities would best predict bull-fighting performance.

METHODS

Experimental approach to the problem

A cross-sectional study was employed whereby high-performing rodeo athletes' anthropometric profile and strength and power qualities were compared between events (bareback-riders [bareback], bull-riders, saddlebronc-riders [saddlebronc], bull-fighters [fighters]) and competition levels (amateur, low-professional [bottom 1/3rd of national rankings], medium-professional [middle 1/3rd of national rankings], high-professional [top 1/3rd of national ranking], internationally ranked professional). General and anthropometric data included age, years of experience, height, body mass, body mass index (BMI), and body fat percentage. Strength measures included isometric hip adduction and abduction, neck flexion and extension, and handgrip dynamometry. Jump measures included squat jump (SJ) and countermovement jump (CMJ) vertical height, eccentric utilization ratio (EUR), reactive strength index (RSI), and pneumatic resisted lateral jump power. Upper body power was assessed via pneumatic resisted chest-press and rotational push-pull tests. Change of direction and anaerobic power were assessed by pro-agility, and air bike sprint tests, respectively. Analysis of variance (ANOVA), standardized differences, and correlational analyses were employed.

Subjects

Forty-three amateur (n=9), national (n=23), or internationally (n=11) ranked adult male rodeo athletes (26.8±5.6 years) volunteered for this study. Subjects consisted of 9 bareback riders, 16 bull-riders, 7 saddlebronc riders, and 11 fighters. All subjects were from Alberta or Saskatchewan, Canada. Written consent was read, signed, and collected from each athlete. The study was approved by the University of Alberta Ethics Committee and was carried out according to the Declaration of Helsinki.

Measurement reliability

All tests without pre-existing publications describing intra- and inter-session reliability were examined during pilot testing with a group (N=8) of similarly aged (29.1±4.8 years) male sports medicine professionals. Intra-session reliability was determined by performing each test (except for anaerobic power) three times per session, with inter-session reliability assessed over two sessions, 6-8 days apart. Reliability was considered acceptable when intraclass correlation coefficient (ICC)>0.67 and coefficient of variation (CV)<10% (32). 95% confidence limits (95%CL) are provided in [square brackets].

Testing procedures

Testing for each subject was completed on a single day, in a private clinic and athlete performance facility. All testing took place between 8 am and 3 pm and followed the same testing order for each subject. Most subjects were assessed during one of four testing combines between May 2021 and March 2022. The following testing procedures followed concussion (SCAT-3), ocular-motor, psychological, and general medical screening.

Body composition

Height was measured to the nearest 1-mm using a stadiometer, while a portable scale measured body mass to the nearest 0.1 kg (both measurements taken barefoot). All skinfold landmarks were measured and denoted by an ISAK level-2 certified anthropometrist with a low typical error (CV=2.8%). The three-site (pectoral, abdominal, thigh) measurements were performed on all subjects three times, in revolving order from one spot to the next. Harpenden callipers (Baty Intl, West Sussex, UK) with a 0.1 cm precision were used to quantify skinfold thickness. The average of the three measures was recorded and entered the Jackson-Pollock equation (**Eq. 1**) to determine body density converted to body fat percentage using the Siri formula (**Eq. 2**).

Equation 1. Body Density=1.10938–(0.0008267×Sum of skinfolds)+(0.0000016×Square of the sum of skinfolds)–(0.0002574×age)

Equation 2. Body Fat Percentage (%)=(495/Body Density)–450

A previous study determined no significant difference (p=0.38) existed in body fat estimates between three and seven site testing (3). Additionally, Loenneke et al. (21) reported strong reliabilities (ICC=0.992) for the Jackson-Pollock three-site estimate.

Warmup

Before the performance tests, all subjects performed a general warmup consisting of forward and backwards jogging, side shuffles, arm swings, lunges, hops, and groin squeezes. Each subject completed the following evaluations post-warmup, with ~5 minutes of rest between tests.

Isometric performance

Specific warmups for all six isometric tests detailed below consisted of performing contractions of 50% and 80% of perceived maximal effort for 5 seconds with 30 seconds between contractions. Isometric hip adduction and abduction were measured in two supine positions using the ForceFrame (Vald Performance, Albion, Australia) sampling at 400 Hz. First, the athletes lay supine with their hips and knees flexed to 45º and 90º (bent-leg) respectfully, with the medial and lateral condyles of the knees between the load cells (**Figure 1A**). Arms and feet were required to be flat on the ground, with the head resting on a pad. Subjects were instructed to apply light pressure to the load cells following the warmup. They were given a countdown of "3, 2, 1, squeeze, squeeze, squeeze!", or "3, 2, 1, push, push, push!" for adduction and abductions, respectively.

Maximal adduction and abduction contractions were performed twice, with 60 seconds of passive rest between each effort. A third contraction was allowed if the force of the second contraction exceeded the first by more than 10%. After a two-minute rest, the same procedures were repeated with the knees and hips extended to 0º (straight-leg) and subjects squeezing and pushing from the medial and lateral malleolus, respectively (**Figure 1B**). For subsequent analysis, the highest force output (newtons) from each limb was recorded. Previous studies have determined assessments of peak hip strength using this equipment to be highly reliable (ICC=0.82-0.85) (12), CV=4.9-9.0% (34)).

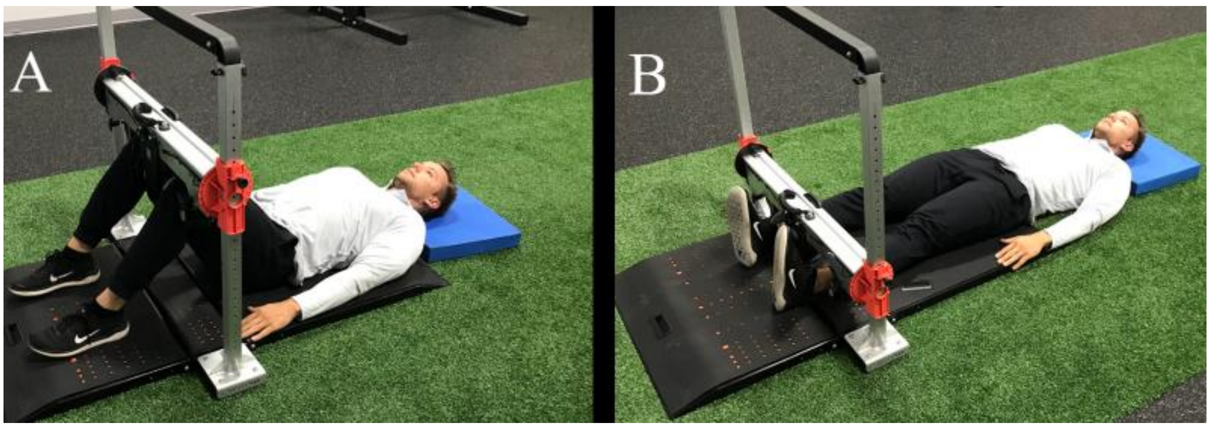

Figure 1. Testing positions for bent- (panel A) and straight-leg (panel B) hip adduction and abduction.

Isometric neck extension and flexion strength were also assessed using the ForceFrame. The athletes assumed a quadruped position for neck extension with their hands placed directly under their heads with elbows locked and the occipital protuberance pressed against a load cell (**Figure 2A**). Following the specific warm-up, subjects applied light pressure to the load cells and were given a countdown of "3, 2, 1, push, push, push!". Maximal contractions were performed twice, with 60 seconds of passive rest. A third contraction was allowed if the second force exceeded the first by >10%. After a two-minute rest, the same procedures were repeated for neck flexion, where the subjects lay supine with the load cell placed minimally above their forehead (**Figure 2B**). A previous study determined isometric neck extension and flexion peak force to be highly reliable when utilizing the same equipment (ICC=0.962-0.986) (24).

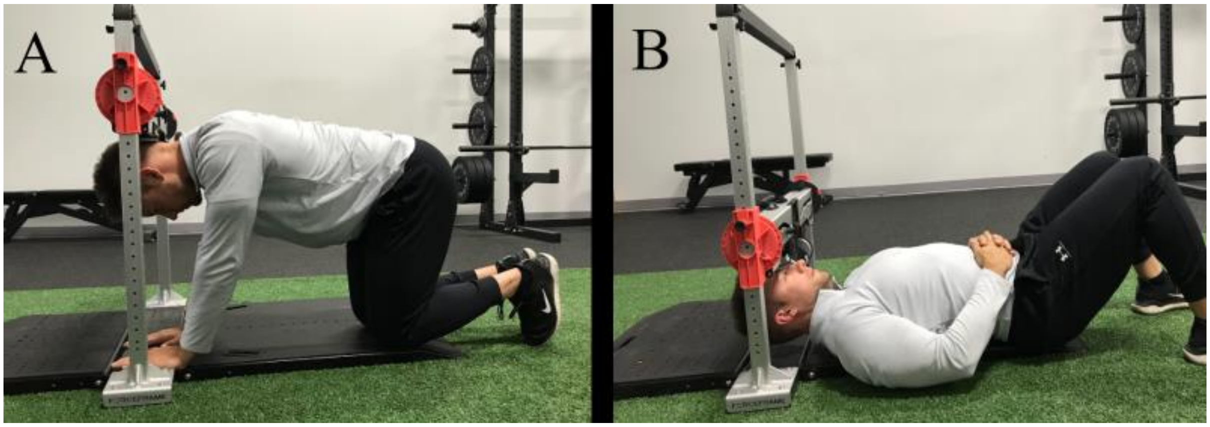

Figure 2. Testing positions for isometric neck extension (panel A) and flexion (panel B).

Isometric grip strength was evaluated with the subjects seated upright with hips and knees at 90º. The hand dynamometer (Baseline Hydraulic, Fabrication Enterprises Inc. White Plains, NY, USA) was set to '0' for consistency and held with the elbow at 90º and the humorous abducted 15º from the torso. Each subject was given one practice squeeze for each hand before performing two maximal efforts per hand, alternatingly with 30 seconds of rest between efforts. The highest force (kg) from each hand was recorded and analyzed. Previous studies have determined handgrip dynamometry to be highly reliable in both healthy athletic (ICC=0.94-0.98) (16) and injured populations (ICC=0.936-0.974) (6), regardless of hand preference.

Dynamic performance

Jump heights were determined by a contact mat (Just Jump, Probotics Inc., Huntsville, AL, USA) which measures flight time to derive jump height ($height=g \cdot t_{fligth}/2$, where g is the acceleration due to gravity). Despite systematically overestimating vertical jump height, contact mats have been found to have nearly perfect correlations to motion capture (r=0.97) and force plates (r=0.99) (20). Subjects performed three SJs and three CMJs with 30 seconds of rest between each jump. For the SJ, the athlete descended to a knee angle of ~90º. This position was held for 3 seconds before a verbal command to jump was given. A SJ was considered successful if the athlete gave a maximal effort and there was no visible countermovement. The CMJ was performed with a rapid descent to a self-selected depth, immediately followed by a maximal ascent. Subjects were instructed not to tuck their legs, and land flat footed during both SJ and CMJ assessments. The highest of each jump type was used for further analysis. The EUR was also calculated by dividing CMJ height by SJ height (25).

The RSI' 10/5' was measured via a wearable accelerometer (PUSH Inc., Toronto, ON, Canada), sampling at 200 Hz, and was automatically derived from: $9.81/8 \times \text{flight-time}^2$. The accelerometer was placed in the manufacturer-provided waist belt and attached to the subjects so that the accelerometer was immediately above the sacrum. The subjects were instructed to have their hands-on-hips and perform ten vertical jumps in rapid succession. The subjects were told to keep their legs relatively straight and "jump as high and fast as possible". Similar to previously examined drop-jump RSI (43), our pilot testing determined the RSI 10/5 testing procedure to hold acceptable intra- (ICC=0.97 [0.89-0.99], CV=6.2% [4.5-11.6) and inter-session (ICC=0.97 [0.86-0.99], CV=6.0% [4.0-12.7]) reliabilities.

A pneumatic cable station (Model 3020; Keiser, Fresno, CA, USA) was used to measure power during the lateral jump, rotational push-pull, and chest-press performances, as illustrated in **Figures 3A, B, and C**, respectively. The pneumatic cable station was chosen to assess several measures of general athletic performance while maximizing space and time efficiency during the collection periods. Resistance was set to 1.52 kilopascals kPa per kilogram of body mass (i.e., 20 psi for a 200 lbs individual) for all pneumatic tests. The order of sides for the lateral jump and push-pull tests were allocated randomly. The subjects were secured to a cable at the '4' height with a waist belt and carabiner for the lateral jump. The subjects were instructed to balance on the leg closest to the station while standing perpendicular. They then bent at the hips and knees, letting the far leg dip behind the down leg before rapidly jumping as far as possible from the cable station (**Figure 3A**). The athletes could land on one or two legs as they preferred. Two practice jumps were allowed before each limb's three maximal efforts were completed with ~15 seconds between jumps and 60 seconds between limbs. Two minutes later, the subjects completed the push-pull rotational power assessment (Figure 3B). For the push-pull test, the pushing and pulling handles were set to '8' and '6', respectively. The athlete began in a semi-squat position before rapidly and simultaneously pushing and pulling on the respective handles. Three practice repetitions were required, followed by three maximal efforts with ~10 seconds between repetitions. The process was repeated on the opposite side following a 60-second break. After two minutes of passive rest, the Keiser's arms were put to a height of '8' with the 'chop bar' attached to both cables for the chest press. The athletes assumed a split stance to aid balance and were instructed to grasp the bar with both hands, palms down, and shoulder-width apart. They then were asked to rapidly press the bar away from their chests (**Figure 3C**). Subjects were given three practice repetitions before a passive rest of 60 seconds. They then performed three maximal repetitions with ~10 seconds between repetitions. The highest peak power output (watts) for each test was recorded for future analyses. Acceptable reliabilities were found for all tests:

- Lateral jump (intra: ICC=0.94 [0.72-0.99], CV=3.9% [2.6-9.2]; inter: ICC=0.95 [0.76-0.99], CV=3.9% [2.5-8.2%])
- Push-pull (intra: ICC=0.91 [0.67-0.98], CV=4.9% [2.9-9.4%]; inter: ICC=0.94 [0.76-0.99], CV=4.2% [2.7-9.1%])
- Chest press (intra: ICC=0.93 [0.68-0.99], CV=4.4% [2.8-9.1%]; inter: ICC=0.94 [0.73-0.99], CV=3.9% [2.6-8.1%])

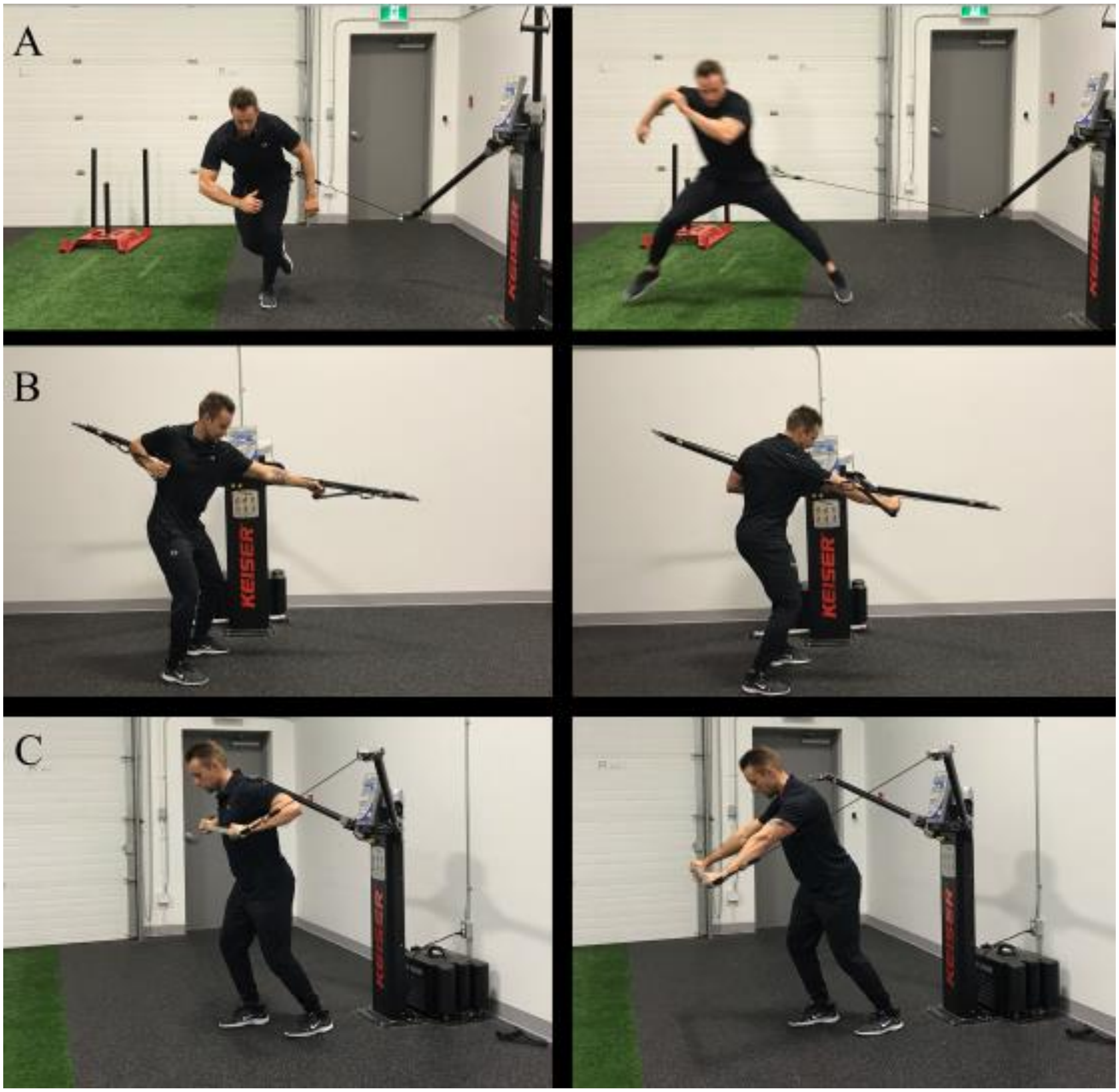

Figure 3. Start and ending positions for the lateral jump (panel A), push-pull (panel B), and chest-press (panel C) power tests.

Change of direction ability was evaluated using the pro-agility test (40). A two-meter-wide lane of cones was laid out five meters apart on an artificial turf surface. Lines between the cones were applied with athletic tape so that the subjects had something to touch during the test. Laser-based timing gaits (Brower Timing Systems, Draper, UT, USA) were set up over the middle cones, 0.75 meters above ground height. Subjects were instructed to face one of the lasers perpendicular to the running direction, and on their own time, sprint to one side, touch the line with one hand while changing direction and sprinting to the far cone. After touching the distant line, the subjects would sprint through the center cones, tripping the timing gates and ending the test. Subjects performed two practice trials at 50% and 75% of perceived maximal effort in each direction. Two maximal trials were then conducted in each direction, in alternating order, with 60 seconds of passive rest between attempts. The fastest time from each direction was recorded for analysis. The pro-agility test is moderate to highly reliable in male team sport athletes (CV=2.5%, ICC=0.67) (40).

Testing was concluded with a maximal effort sprint on an air bike (TYDAX, Edmonton, Canada). Subjects rode with hands and feet cycling simultaneously. The bike was set to record the time taken to burn ten calories (kcal). Subjects rode the bike at 50% of perceived maximal effort for 60 seconds before a 60-second rest. A researcher then gave a countdown of "3, 2, 1, GO!" before the subject exerted maximal effort until ten kcal were registered. Pilot testing determined the anaerobic power test to hold acceptable intersession reliability (ICC=0.85 [0.65-0.99], CV=4.9% [3.2-10.2%]).

Statistical analysis

Jeffrey's Amazing Statistics Program (JASP) software (version 0.16, Amsterdam, Netherlands) was used for all statistical analyses. Results were analyzed for the entire group and each event (bareback, bull-riders, saddlebronc, fighters) utilizing an ANOVA, with Welch's homogeneity correction, for each primary variable. Dunn's Post-hoc comparisons were employed to quantify pairwise comparisons. Qualitative descriptors of standardized Cohen's *d* effect sizes (ES) with 95%CL were assessed and reported using these criteria: trivial <0.2, small 0.2–0.49, moderate 0.5–0.79, large >0.8 (14). Due to the limited sample size, results were interpreted as potentially meaningful when ES≥0.50. P-values are provided to express the precision of the mean estimated difference between events (42). At the same time, statistical significance was accepted when $p<0.05$. Omega squared (ω^2) was used to characterize the effect size of each ANOVA (14).

Both magnitude and precision of the estimated difference (i.e., ES and *p*-values) were used to interpret the results.

Spearman's Rho (ρ) assessed relationships between the testing variables and competitive level (1=amateur, 2=low-professional, 3=medium-professional, 4=high-professional, 5=international-professional). Pearson's correlation (*r*) coefficient assessed relationships between anthropometric and performance variables. Spearman's correlations were performed for all riders (n=32) pooled, while fighters (n=11) were analysed separately. All correlations were interpreted as: = ±0 to 0.1 trivial, ±0.1 to 0.3 small, ±0.3 to 0.5 moderate, ±0.5 to 0.7 large, ±0.7 to 0.9 very large, and <-0.9 or >0.9 nearly perfect. Additionally, 95%CL were calculated for the correlational data by simulating 1000 bootstrapped samples. Moderate results were interpreted as potentially meaningful.

Normative data are reported as mean±standard deviation (SD) in tables, while medians, interquartile ranges, and minimum and maximum values are presented in box-plot form due to instances of non-normally distributed data. Individual data points and distributions were included to provide further transparency (2, 44). Asymmetry percentages are provided for all unilateral performance measures. Due to many possible comparisons, only significant or potentially meaningful results are reported in the text. Similarly, superfluous correlations (e.g., BMI/body fat %, CMJ height/non-dominant grip strength) are not reported in text.

RESULTS

Total group and event-specific age, experience, and anthropometric characteristics, isometric performance data, and dynamic performance data are summarized in **Tables 1**, **2**, and **3**, respectively.

Table 1. Anthropometric characteristics by rodeo event

Event	Age (yrs)	Total rodeo experience (yrs)	Experience in current event (yrs)	Height (cm)	Weight (kg)	BMI (km/m^2)	Body-fat (%)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Bareback (n = 9)	26.6 ± 6.8	12.4 ± 9.8	11.3 ± 6.9	177.2 ± 6.1	78.2 ± 6.7	24.9 ± 2.4	9.1 ± 5.5
Bull-riders (n = 16)	24.3 ± 4.4	13.0 ± 6.5	9.3 ± 4.7	174.8 ± 4.3	70.8 ± 8.2	23.1 ± 2.3	7.5 ± 4.9
Saddlebronc (n = 7)	29.7 ± 5.4	19.4 ± 4.9	14.2 ± 4.7	175.7 ± 7.8	75.7 ± 15.9	24.2 ± 4.9	10.5 ± 7.5
All riders (n = 32)	26.1 ± 5.6	13.9 ± 7.5	10.7 ± 5.5	175.7 ± 5.6	74.0 ± 10.2	23.9 ± 3.0	8.6 ± 5.7
Bull-fighters (n = 11)	28.9 ± 5.9	14.6 ± 4.9	10.0 ± 6.0	179.8 ± 5.0	78.3 ± 4.7	24.3 ± 1.6	13.6 ± 5.1
Total (N = 43)	26.8 ± 5.3	14.1 ± 6.9	10.5 ± 5.6	176.6 ± 5.6	75.0 ± 9.3	24.0 ± 2.8	9.3 ± 5.5

SD = standard deviation. Body-fat % = Jackson and Pollock three-site estimate.

Table 2. Isometric performance characteristics

Test	Bareback (n = 9)	Bull-riders (n = 16)	Saddlebronc (n = 7)	All riders (n = 32)	Bull-fighters (n = 11)	Total (N = 43)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Hip (N)						
Bent-leg adduction (average)	484 ± 81	464 ± 96	459 ± 107	469 ± 92	502 ± 65	476 ± 87
Average asymmetry (%)	4.1 ± 1.8	7.3 ± 5.7	5.2 ± 4.8	6.2 ± 4.8	7.7 ± 6.5	6.5 ± 5.3
Bent-leg abduction (average)	457 ± 74	392 ± 67	380 ± 92	408 ± 79	403.7 ± 68	407 ± 76
Average asymmetry (%)	4.1 ± 2.4	5.7 ± 4.0	5.7 ± 4.6	5.2 ± 3.7	5.1 ± 2.3	5.1 ± 3.4
Adduction: abduction (% diff)	6.5 ± 18.5	17.3 ± 19.5	24.9 ± 29.1	15.6 ± 21.3	25.9 ± 16.9	18.5 ± 20.3
Straight-leg adduction (average)	219 ± 59	224 ± 48	230 ± 53	224 ± 51	237 ± 61	227 ± 53
Average asymmetry (%)	5.1 ± 2.6	5.3 ± 4.2	6.7 ± 3.9	5.5 ± 3.7	8.3 ± 7.9	6.2 ± 4.8
Straight-leg abduction (average)	210 ± 62	191 ± 47	198 ± 42	198 ± 50	185 ± 45	195 ± 48
Average asymmetry (%)	7.3 ± 7.4	3.8 ± 4.9	3.6 ± 2.4	4.8 ± 5.5	6.5 ± 5.4	5.1 ± 5.5
Adduction: abduction (% diff)	6.7 ± 18.0	21.0 ± 26.4	23.8 ± 18.8	17.4 ± 23.4	28.1 ± 19.9	20.3 ± 22.3
Bent-leg: straight-leg diff						
Adduction (%)	139 ± 53.8	109 ± 35.7	89.7 ± 25.6	113.6 ± 42.6	121 ± 43.4	116 ± 41.6
Abduction (%)	135 ± 32.9	116 ± 52.8	89.0 ± 12.5	117 ± 44.6	123 ± 34.8	119 ± 41.2
Neck (N)						
Flexion	169 ± 36	182 ± 75	168 ± 43	175 ± 58	157 ± 60	171 ± 58
Extension	321 ± 76	340 ± 76	278 ± 55	320 ± 73	315 ± 94	319 ± 78
Flexion: extension (% diff)	46.0 ± 9.9	44.8 ± 22	43.1 ± 12.7	44.8 ± 17.2	50.7 ± 11.4	46.4 ± 16.0
Grip (kg)						
Mean	54.4 ± 13.0	52.6 ± 9.4	55.9 ± 5.8	53.8 ± 9.7	54.3 ± 9.2	55.0 ± 9.1
Dominant	55.9 ± 12.7	54.5 ± 9.3	56.5 ± 5.9	55.1 ± 9.5	54.8 ± 8.4	53.0 ± 10.5
Non-dominant	53.0 ± 14.5	50.8 ± 10.8	55.5 ± 7.0	52.5 ± 11.1	54.4 ± 8.6	53.9 ± 9.5
Average asymmetry (%)	11.7 ± 13	10.8 ± 11.3	2.5 ± 3.1	9.8 ± 11.2	2.9 ± 3.2	7.8 ± 10.1

SD = standard deviation. N = newtons. kg = kilograms

Table 3. Dynamic performance characteristics

Test	Bareback (n = 9)	Bull-riders (n = 16)	Saddlebronc (n = 7)	All riders (n = 32)	Bull-fighters (n = 11)	Total (N = 43)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Vertical jump						
CMJ (cm)	57.9 ± 3.8	60.0 ± 8.9	57.7 ± 4.8	58.9 ± 6.9	58.8 ± 4.3	58.8 ± 6.4
SJ (cm)	48.8 ± 8.5	47.3 ± 7.5	47.6 ± 6.0	47.8 ± 7.3	48.6 ± 2.1	48.0 ± 6.5
% difference	13.7 ± 17	18.9 ± 6.2	18.1 ± 10.4	17.3 ± 10.8	17.0 ± 4.7	16.9 ± 9.6
EUR	1.22 ± 0.20	1.24 ± 0.10	1.24 ± 0.13	1.23 ± 0.14	1.21 ± 0.07	1.23 ± 0.12
RSI 10/5	1.12 ± 0.37	1.18 ± 0.56	0.85 ± 0.43	1.09 ± 0.49	1.50 ± 0.29	1.19 ± 0.48
Pneumatic power (W)						
Lateral bound (average)	201 ± 26.3	188 ± 25.3	190 ± 26.6	192 ± 25.9	201 ± 23.3	194 ± 25.0
Average asymmetry (%)	4.7 ± 3.2	6.7 ± 5.0	6.6 ± 7.0	6.1 ± 4.9	4.6 ± 2.3	5.8 ± 4.4
Push-pull (average)	911 ± 156	864 ± 154	831 ± 109	870 ± 144	903 ± 146	878 ± 143
Average asymmetry (%)	10.0 ± 4.8	11.0 ± 11	3.9 ± 2.9	9.3 ± 8.7	5.9 ± 6.3	8.4 ± 8.2
Chest-press	632 ± 110	630 ± 113	586 ± 193	621 ± 130	618 ± 75.4	621 ± 117
COD (sec)						
Pro agility (average)	5.07 ± 0.36	5.00 ± 0.49	5.32 ± 0.26	5.07 ± 0.42	4.95 ± 0.37	5.04 ± 0.41
Average asymmetry (%)	2.5 ± 1.3	2.5 ± 2.4	3.9 ± 4.0	2.8 ± 2.5	2.9 ± 1.8	2.8 ± 2.3
Anaerobic power						
10 kcal air-bike (sec)	15.1 ± 2.4	16.7 ± 3.1	15.3 ± 3.1	16.0 ± 2.9	15.1 ± 1.7	15.6 ± 2.7

SD = standard deviation. CMJ = countermovement jump. SJ = squat jump. EUR = eccentric utilization ratio. cm = centimetres. W = watts. RSI = reactive strength index. COD = change of direction. sec = seconds.

Between-event differences

No significant interaction effects (F=0.338, p=0.798, ω^2<0.001) or pairwise comparisons (ES≤0.47, p≥0.15, ≤24%) were detected for competitive level (**Figure 4**).

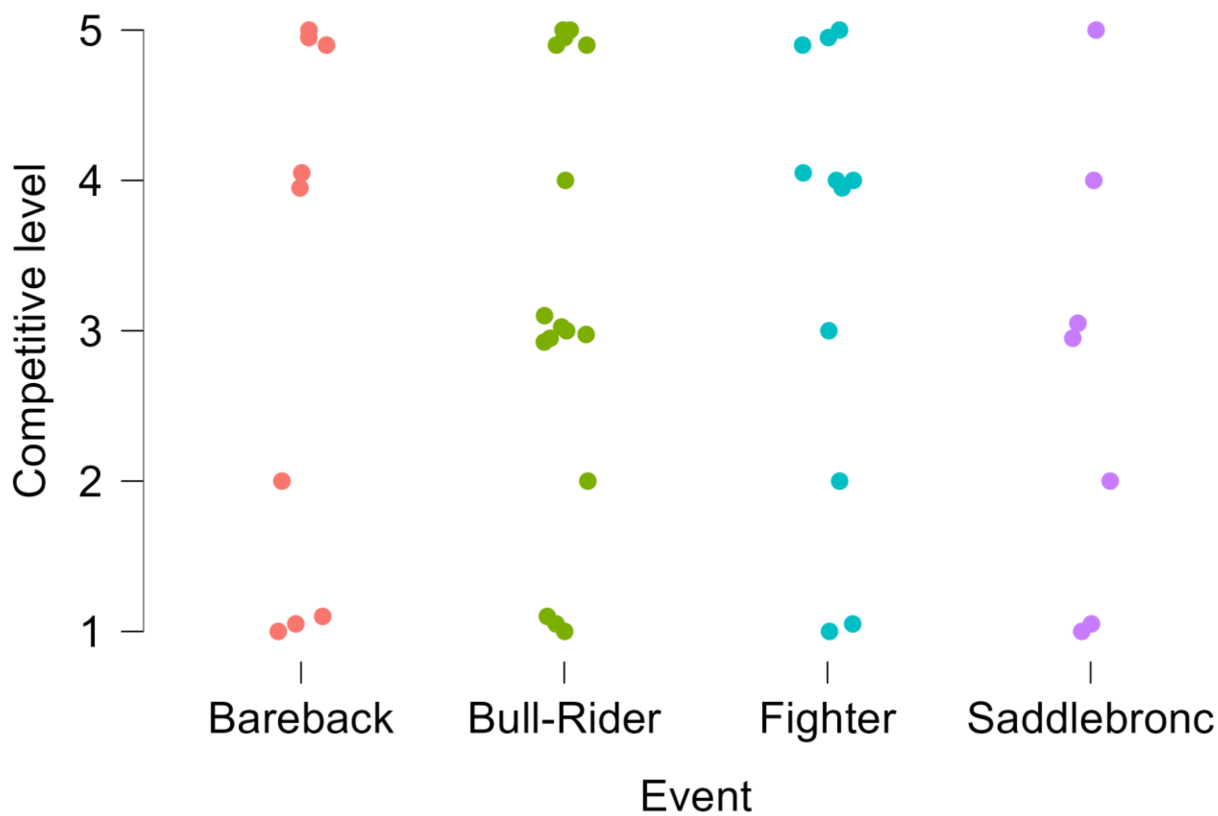

Figure 4. Jitter plot of competitive level between rodeo events. 1=amature, 2=low national, 3=medium national, 4=high national, 5=internationally ranked.

Anthropometrics

Individual age, experience, and anthropometric characteristics are illustrated in **Figure 5.** No significant interaction effects were detected (F=1.21-3.05, p=0.057-0.335, ω^2<0.001-0.097) for age, experience or any anthropometric variables. However, Dunn's post-hoc analysis also found that fighters (ES=0.87 [-0.25 – 2.00], p=0.013, 17.3%) and saddlebronc (ES=1.02 [-0.28 – 2.32], p=0.012, 20.0%) athletes were older than the bull-riders. Post-hoc determined that saddlebronc-riders had more years of rodeo experience than bareback-riders (ES=1.04 [-0.59 – 2.67], p=0.036, 44.2%), and bull-riders (ES=0.95 [-0.52 – 2.40], p=0.033, 39.5%). Similarly, saddlebronc riders had greater event experience than the bull-riders (ES=0.89 [-0.57 – 2.35], p=0.027, 42.2%). Post-hoc comparisons also determined that fighters were taller than saddlebronc (ES=0.71 [-0.68 – 2.10], p=0.037, 2.2%) and bull-riders (ES=0.87 [-0.28 – 2.03], p=0.008, 2.7%), while bull-riders were lighter than barebacks (ES=0.83 [-0.36 – 2.02], *p*=0.018, 10.0%) and fighters (ES=0.84 [-0.32 – 1.99], *p*=0.017, 10.1%). Finally, bull-riders had lower body-fat percentage than the fighters (ES=0.74 [-0.41 – 1.88], *p*=0.012, 42.2%).

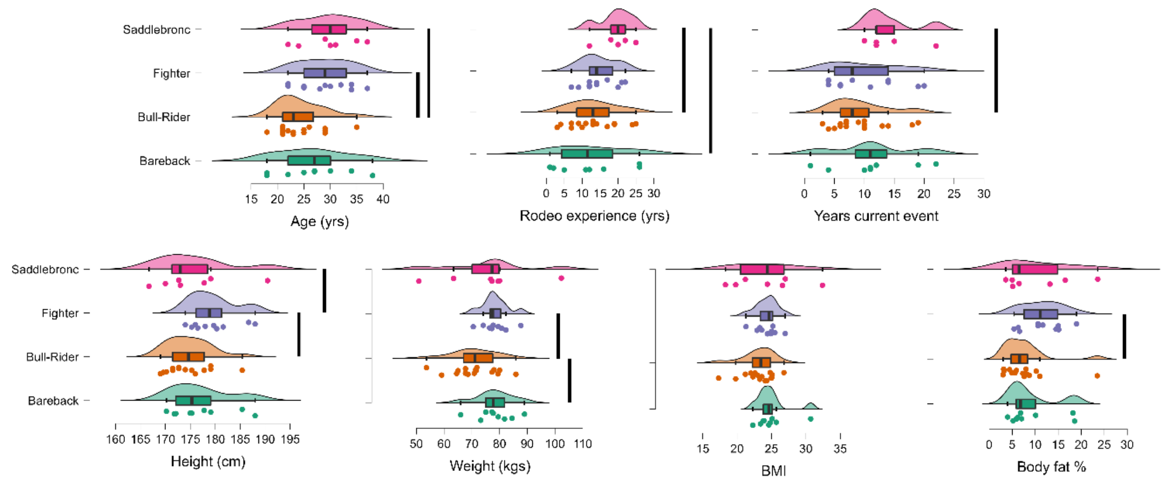

Figure 5. Raincloud plots of individual age, experience, and anthropometric data between rodeo events. Box plots illustrate the median, interquartile range, and minimum and maximum values. Individual data points beyond the whiskers are considered outliers (quartile±1.5×interquartile range). Black bars=significant pairwise difference (*p*<0.05).

Isometric performance

Individual isometric performance data are illustrated in **Figure 6**. No significant interaction effects were detected (*F*=0.043-1.73, *p*=0.200-0.988, ω^2<0.001-0.064) for any isometric variables. However, Dunn's post-hoc comparisons showed that bareback riders had higher bent-leg hip abduction when compared to saddlebronc (ES=1.06 [-0.39 – 2.50], *p*=0.026, 18.5%) and bull-riders (ES=0.89 [-0.30 – 2.09], *p*=0.019, 15.4%). Post-hoc analysis also determined that bull-riders had greater neck extension strength than the saddlebronc-riders (ES=0.79 [-0.51 – 2.10], *p*=0.040, 20.0%). Straight-leg hip abduction was meaningfully higher in bareback riders when compared to fighters (ES=0.51 [-0.78 – 1.80], *p*=0.184, 12.6%). Neck extension was also meaningfully higher in bareback when compared to saddlebronc riders (ES=0.56 [-0.86 – 1.97], *p*=0.127, 14.4%)

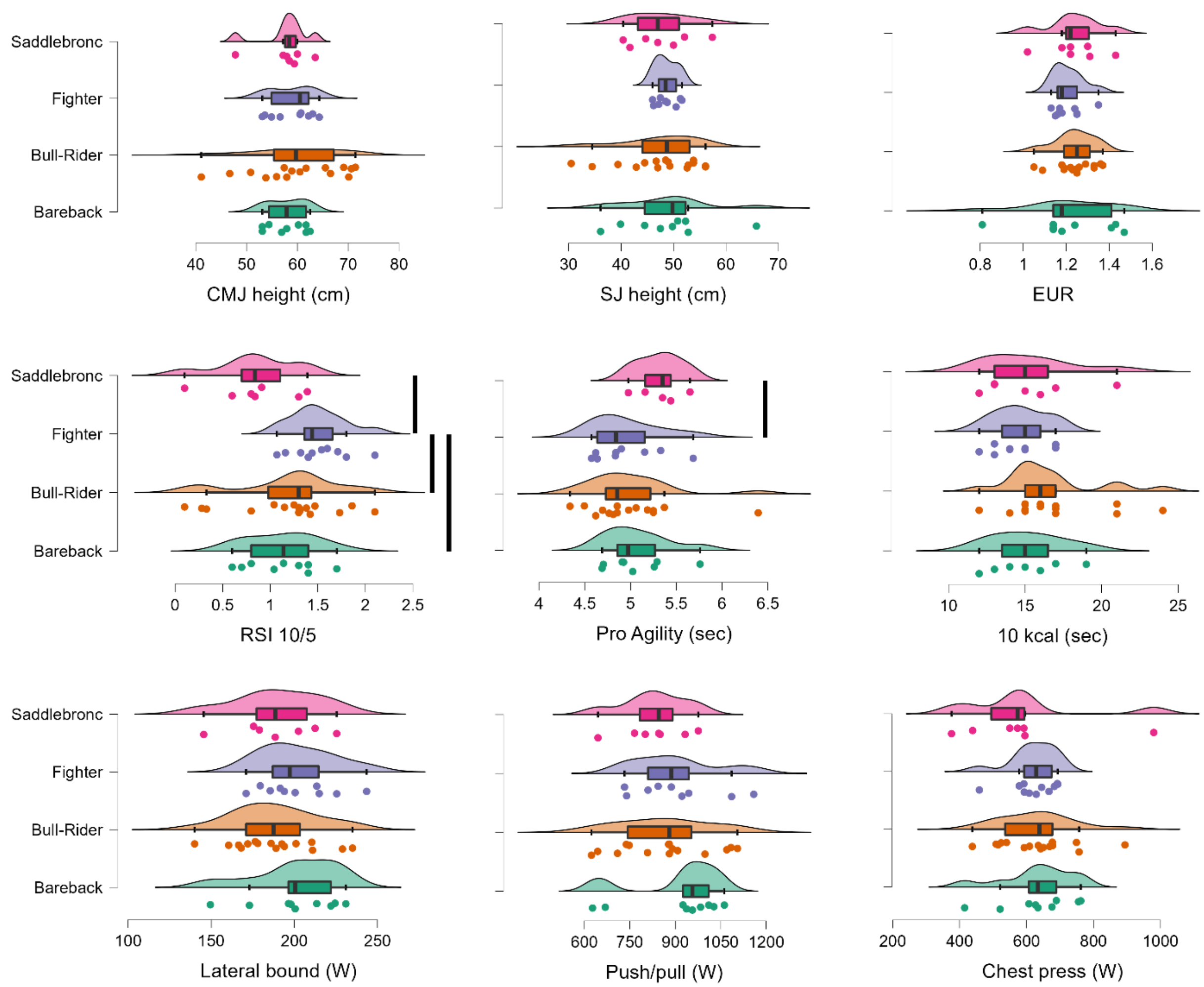

Figure 6. Raincloud plots of isometric performance data between rodeo events. Box plots illustrate the median, interquartile range, and minimum and maximum values. Individual data points beyond the whiskers are considered outliers (quartile±1.5×interquartile range). Black bars=significant pairwise difference (p<0.05).

Dynamic performance

Individual dynamic performance data are illustrated in **Figure 7**. A significant interaction was detected for RSI (F=4.83, p=0.012, ω^2=0.136) with post-hoc analysis determining that fighters had greater RSI when compared to bareback (ES=0.86 [-0.42 – 2.14], p=0.014, 29.3%), saddlebronc (ES=1.47 [-0.05 – 2.89], p<0.001, 55.7%), or bull-riders (ES=0.73 [-0.38 – 1.85],

p=0.030, 24.5%). Dunn's post-hoc analysis determined found that bareback riders had meaningfully greater RSI than saddlebronc riders (ES=0.61 [-0.81 – 2.02], p=0.162, 27.7%).

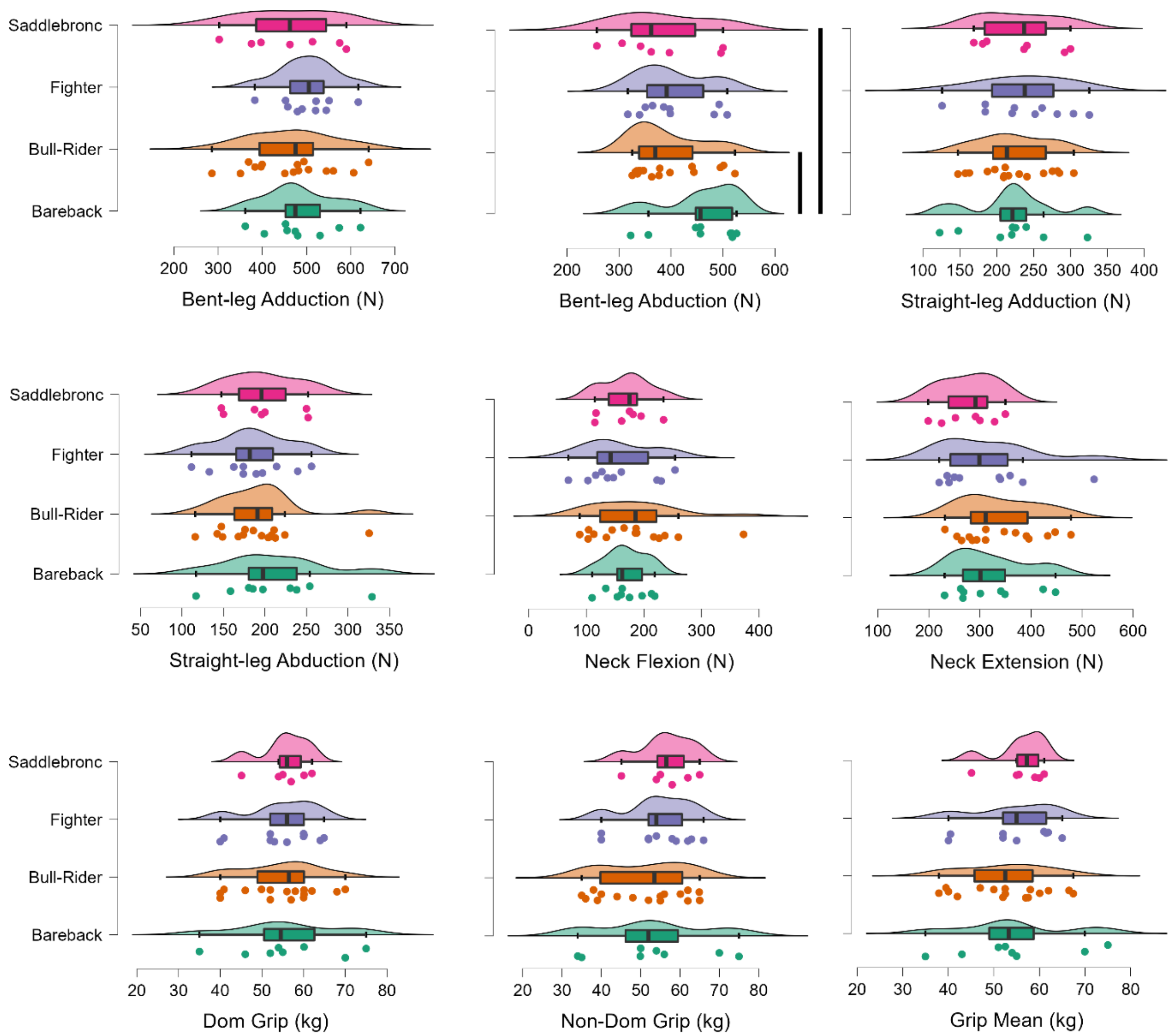

Figure 7. Raincloud plots of dynamic performance data between rodeo events. Box plots illustrate the median, interquartile range, and minimum and maximum values. Individual data points beyond the whiskers are considered outliers (quartile±1.5×interquartile range). Black bars=significant pairwise difference (p<0.05).

No significant interaction effects were detected (*F*=0.113-0.894, *p*=0.204-0.951, ω^2<0.001-0.021) for any other dynamic variable. Post-hoc comparisons also detected meaningfully lower lateral bound power for the bull-riders when compared to bareback riders (ES= 0.51 [-0.66 – 1.69], *p*=0.077, 6.6%) and fighters (ES=0.55 [-0.58 – 1.69], *p*=0.086, 9.1%). Likewise, saddlebronc had lower push-pull power than the bareback riders (ES=0.55 [-0.87 – 1.97], *p*=0.088, 9.2%). Agility time was significantly or meaninfully slower for saddlebronc riders than fighters (ES=0.88 [-0.71 – 2.48], *p*=0.020, 7.1%), bull-riders (ES=0.78 [-0.70 – 2.25], *p*=0.022, 6.2%), or bareback (ES=0.60 [-1.02 – 2.21], *p*=0.110, 4.7%). Finally, bull-riders had slower 10 kcal time-trials than fighers (ES=0.73 [-0.41 – 1.86], *p*=0.049, 12.4%), bareback (ES=0.57 [-0.72 – 1.86], *p*=0.144, 9.6%), or saddlebronc riders (ES=0.52 [-0.77 – 1.81], *p*=0.129, 8.6%).

Correlations

Heatmaps of Spearman's correlations for riders (n=32) and fighters (n=11) are provided in **Supplementary Figure 1** and **Supplementary Figure 2**, respectively.

Competitive level

Riders

Scatter plots of significant (*p*<0.05) correlations between anthropometric and performance tests, and competitive riding level (bareback-riders, bull-riders, saddlebow-riders pooled) are provided in **Figure 8**. The competitive level of rodeo riders was moderately correlated with age (ρ=0.43 [0.09-0.71], *p*=0.013), and rodeo experience (ρ=0.37 [-0.02-0.71], *p*=0.050). Bent-leg abduction (ρ=0.43 [0.08-0.67], *p*=0.014), and straight-leg adduction (ρ=0.56 [0.25-0.76], *p*<0.001) and abduction (ρ=0.49 [0.12-0.73], *p*=0.005) forces, were moderately correlated with competitive level. Similarly, isometric neck flexion force was moderately correlated with competitive level (ρ=0.43 [0.10-0.68], *p*=0.016). The competitive level of the riders was also moderately correlated with rotational push-pull power (ρ=0.50 [0.17-0.74], *p*=0.004) power.

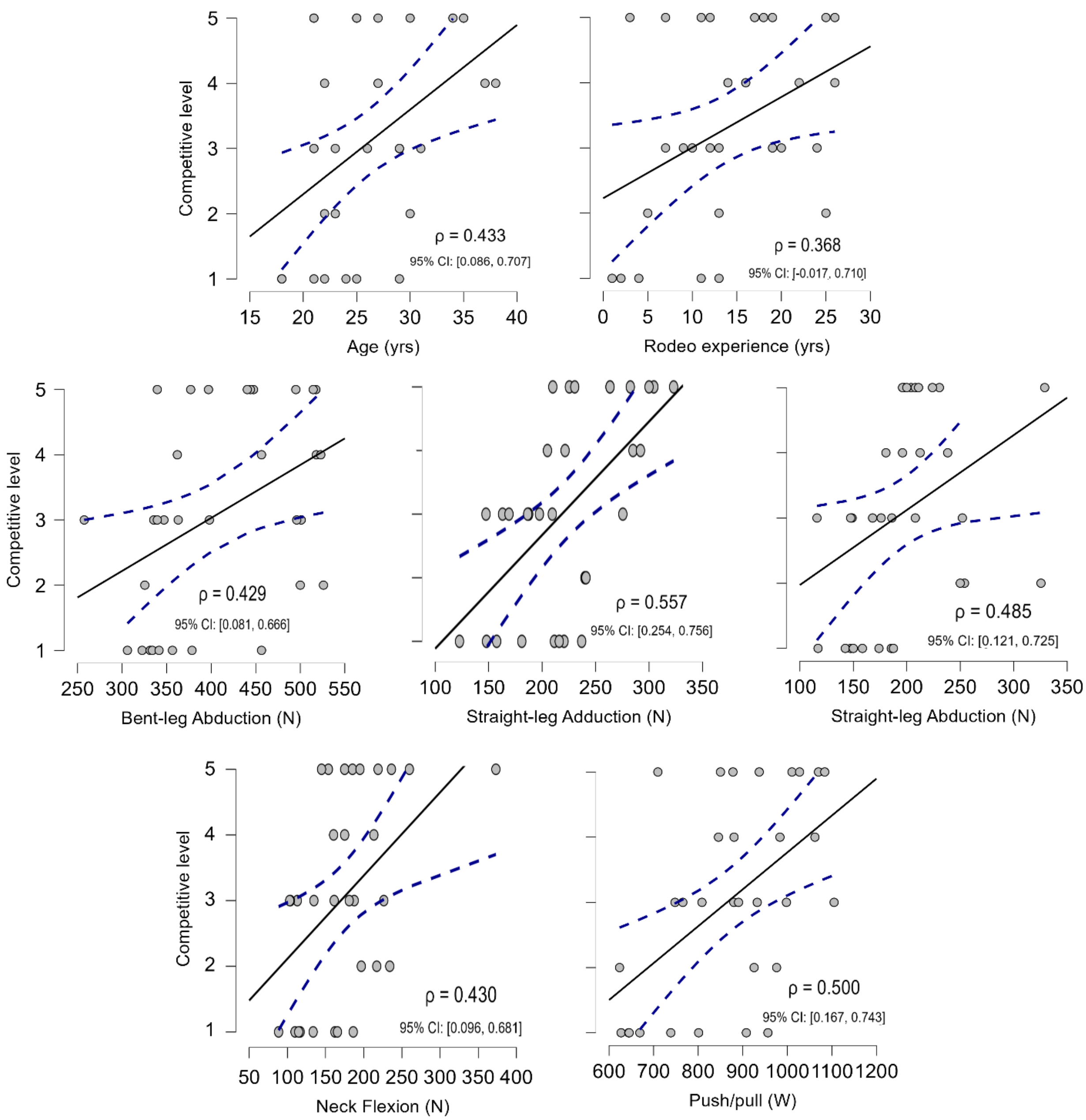

Figure 8. Statistically significant (p<0.05) Spearman's correlations (ρ) between competitive level, and anthropometric and performance characteristics of the pooled riders (n=29).

Non-significant, but possibly meaningful correlations were found between riding level and current event experience (ρ=0.30 [-0.07 – 0.63], *p*=0.112), bent-leg hip adduction (ρ=0.33 [-0.02 – 0.62], *p*=0.063), and lateral bound power (ρ=0.34 [0.01-0.61], *p*=0.058).

Fighters

Scatter plots of significant (*p*<0.05) correlations between anthropometric and performance tests and competitive fighting level are provided in **Figure 9**. Competitive fighting level was moderately correlated with age (ρ=0.64 [0.11-0.90], *p*=0.036), and largely correlated with 10 kcal time-trial performance (ρ=-0.739 [-0.96 – -0.15], *p*=0.009).

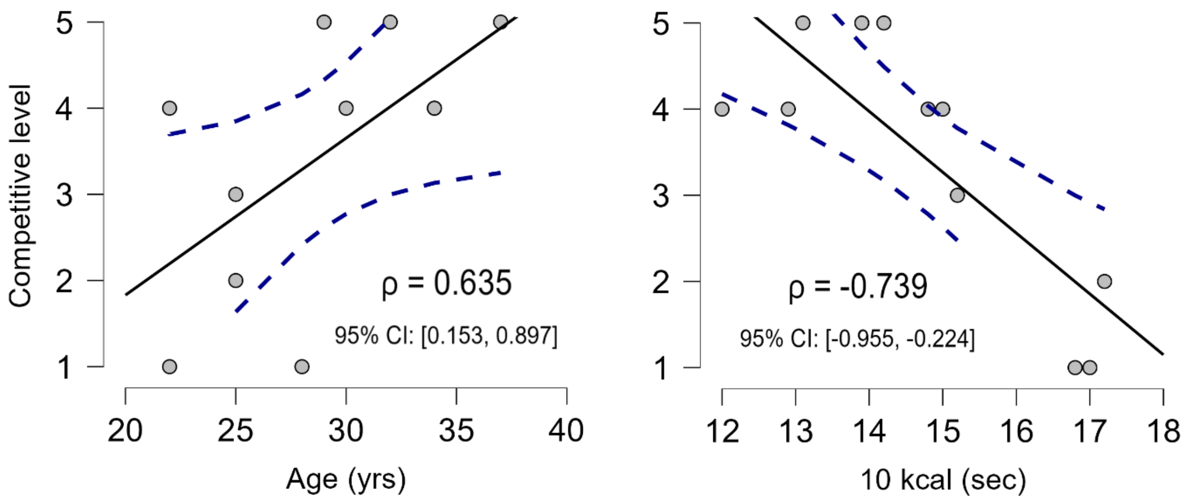

Figure 9. Statistically significant (*p*<0.05) Spearman's correlations (ρ) between competitive level, and anthropometric and performance characteristics of the bull-fighters (n=11).

Non-significant, but potentially meaningful correlations were found between fighting level and rodeo experience (ρ=0.37 [-0.36 – 0.88], *p*=0.261) and current event experience (ρ=0.41 [-0.35 – 0.92], *p*=0.216). Potentially meaningful correlations were also found between competitive level and bent-leg adduction (ρ=0.50 [-0.13 – 0.90], *p*=0.14) and abduction (ρ=0.35 [-0.36 – 0.92], *p*=0.35), straight-leg adduction (ρ=0.56 [-0.10 – 0.94], *p*=0.090) and abduction (ρ=0.40 [-0.33 –

0.93], *p*=0.25). SJ (ρ=0.45 [-0.27 – 0.89], *p*=0.23), RSI (ρ=0.39 [-0.34 – 0.84], *p*=0.24), chest press (ρ=0.47 [-0.11 – 0.88], *p*=0.144) also held potentially meaningful correlations with fighting level.

Performance testing relationships

Heatmaps of Pearson's correlations between all anthropometric and performance variables for all riders and fighters pooled (N=43) are provided in **Supplementary Figure 3**.

DISCUSSION

The purpose of the present investigation was to develop the first normative anthropometric and physical performance data for seldom-studied rodeo athletes. We also aimed to determine which age, experience, anthropometric, and performance characteristics relate to rodeo performance level. The key findings were that age, total rodeo experience, event experience, hip and neck flexion strength, and rotational power were related to riding performance. In contrast, age and anaerobic power were associated with bull-fighting performance. Additionally, fighters had greater RSIs than riding athletes. The potential cultural, physiological, and biomechanical explanations for our findings, and implications for practitioners and researchers are discussed herewith.

Of the riders, bull- were the youngest, with the least rodeo and event experience, followed by bareback- and saddlebronc-riders, respectively. This finding perfectly aligns with longitudinal findings on between-event injury rates reporting that bull-riders suffered the most injuries, followed by bareback and saddlebronc athletes (38). Likewise, fighters were also older and more experienced than bull-riders, lending credence to anecdotes that fighters are commonly former riders who wish to remain active in the rodeo community. Therefore, it is plausible that bull-riders have shorter careers or eventually shift to events with lower injury risk.

The most consistent between-event findings were between bull-riders and fighters, with the bull-riders being shorter, lighter, and leaner than the fighters. Bareback athletes were also heavier than the bull-riders. Due to the greater twisting and turning in bull versus saddlebronc or bareback riding, being shorter and lighter may be advantageous as rotational inertia would be lesser when compared with taller or heavier athletes. However, this theory would have to be confirmed via motion-capture or inertial measurement units. Height, weight, and body fat percentage did not correlate to riding performance for any subgroup or pooled for all riders, suggesting the importance of firm cut-offs instead of linear relationships.

While we hypothesized the importance of adductor strength, all isometric hip adduction and abduction force measures were significantly and/or moderatly correlated with riding (but not fighting) performance, with minimal between-event differences. This finding could be due to several factors, including agonist-antagonist neural inhibition and co-activation (9, 23), or simply that hip adduction and abduction strength are highly associated (r=0.45-0.67, all p<0.01, see Supplementary Figure 3). Regardless, combined with previous research determining the prevalence of hip injuries (39), our findings suggest it is wise for riders to focus on building and maintaining hip strength. However, it is beyond the scope of the present study to determine if building hip strength will directly affect performance or injury risk. Neck strength is another potentially important quality for rodeo athletes, as concussions and head injuries are among the most commonly suffered (8). Our data show that better riders tend to have stronger neck flexors, and previous studies have determined the beneficial effects of neck strength on head kinematics (5, 19) and concussion occurrence (10, 17). However, like hip strength, the relationship between neck strength and concussion risk remains to be determined in a rodeo context. Contrary to our hypothesis, grip strength did not correlate to riding level, suggesting a minimum threshold for performance that is not improved with greater strength. Therefore, riders may not need to prioritize grip training outside of individual circumstances. However, the assessed arm position and dynamometer diameter are substantially different than the gripping position and task during riding events, potentially challenging the test's specificity.

While six of the nine dynamic performance measures found no between-event differences, lateral bound and upper-body rotational power did correlate with riding performance. While not specific to riding, the lateral bound heavily utilizes the hip musculature, which is essential to riding performance and may be a better test for assessing rapid force production. Conversely, the relationship between rotational power and riding performance is more straightforward. This is due to the rotational forces that must constantly be resisted to maintain position on an animal, especially with one hand secured to a rope, with the other held above the riders' center of mass (4). Thus, it is likely that riders should prioritize rotational power and anti-rotation-focused exercises in their physical preparation.

Fighters had significantly greater RSIs and completed the pro-agility and time-trial tests in the shortest times. The RSI and pro-agility results are easily explainable due to specificity as the fighters are the only rodeo event examined that perform on their feet, rapidly changing directions. Therefore, long-term musculotendinous and neural adaptations from rodeo-specific training may be at play. However, neither jump heights nor EUR favoured the fighters, suggesting that potential musculotendinous differences may exist predominantly in the triceps surae complex (1). RSI, pro-agility, and air-bike tests were also the only ones in the testing battery that required repeated contractions/efforts. Therefore, the long rest periods afforded to riders during competition, in contrast with the fighters performing nearly non-stop, may have underpinned the present results. Regardless of the between-group differences, only time-trial performance correlated with fighting competitive level. While challenging to rationalize fully, it is plausible that fighters with greater anaerobic fitness can perform crowd-pleasing stunts regularly, making themselves more likely to be invited to higher-level rodeos.

Limitations

While the primary purpose of the investigation was accomplished, there are several limitations and future research directions of which to be aware. We could not directly measure riding performance, and fighting performance is highly subjective. Therefore, we utilized competitive status to delineate the abilities of the subjects. Similarly, we did not quantify the current training practices of the subjects. It is, therefore, plausible that prize-winning and highly-sponsored athletes have more time and resources to invest in specific physical preparation. Conversely, lower-achieving rodeo athletes may have to rely on physical labour for income, potentially negatively impacting performance.

While challenging to recruit high-level rodeo athletes, our limited individual event sample sizes for bareback- (n=9) and saddlebronc- (n=7) riders made some between-event analyses questionable. This observation is clear as a single outlier could have a large impact, as visually apparent in Figures 5, 6 and 7, and demonstrated by frequently large confidence limits. For example, trivial values are included in the 95%CLs for correlations between riding performance and current event experience, bent-leg adduction, and neck flexion. Also, the physical characteristics of youth and female rodeo athletes and other events such as barrel-racing, calf-roping, and steer wrestling require examination. While we report our inter- and intra-session reliability data for previously un-published tests, our sample size for these data was relatively small (N=8). Therefore, more extensive studies are required to investigate the validity and reliability of the accelerometer-derived RSI 10/5 stiffness, pneumatic power, and 10 kcal time-trial tests.

The pneumatic cable station could only be adjusted in large increments (15°, height: 18.8±7.7 cm (range: 5-27 cm) at the distal attachment points), making personalization based on height difficult. Therefore, readers should know that relative between-participant cable positions were not uniform. Other tests, including strength endurance, or reaction times, may unveil additional findings. Likewise, we did not include any direct measures of core stability (e.g., plank test) or glenohumeral strength that could be critical to riding performance. A lack of range of motion assessment was a similar oversight and warrants investigation. Longitudinal investigations are required to understand how performance characteristics relate to injury and recovery rates. Also, training studies are needed to elucidate the cause-and-effect relationship between physical traits and rodeo performance.

PRACTICAL APPLICATIONS

While previous articles have reported injury (27) or cardiovascular and metabolic data (26) in rodeo athletes, the present study is the first to report normative and correlational strength and power performance data in a rodeo population. From our data, hip strength and upper-body rotational power appear vital for bare-, bull-, and saddlebronc-riders. Therefore, strength and conditioning coaches should consider including hip adduction and abduction-focused exercises like Copenhagen planks, banded adductions, and lateral slide adductions (37). Rotational exercises such as medicine ball throws may also belong in a physical preparation program (13). Neck flexion strength, likely trained via manual isometrics and bridges (15), also seem crucial. Conversely, high anaerobic power and RSI were the most apparent qualities of interest for bullfighters. These data highlight the likely need for greater foci on event-specific physical preparation to maximize performance. Sports medicine professionals can use the normative data when working with rodeo athletes in return-to-sport contexts. Finally, the normative data may increase motivation and facilitate goal setting. We hope that the present study encourages other groups to examine rodeo athletes and bring sports science to this often-forgotten sport.

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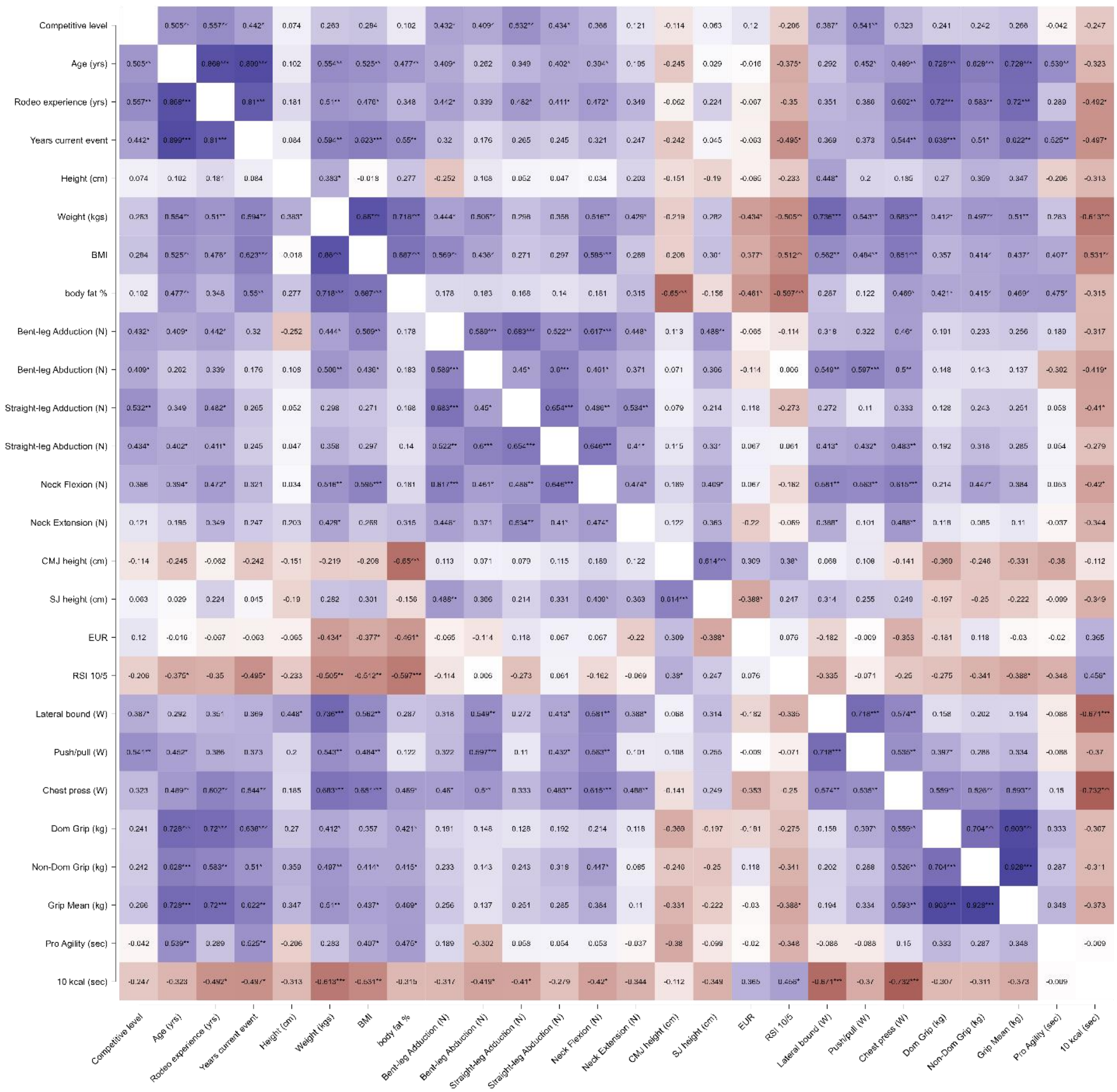
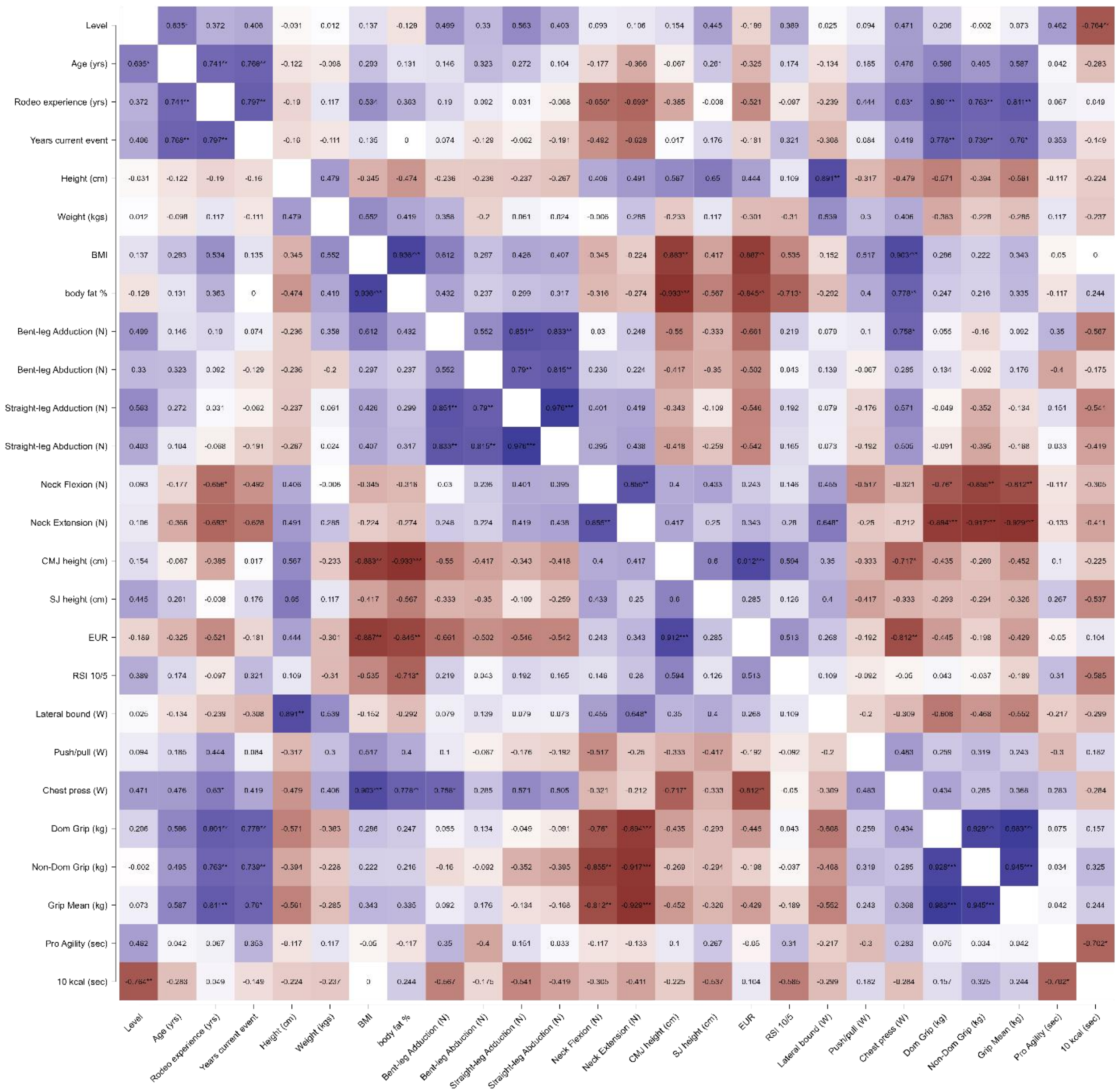
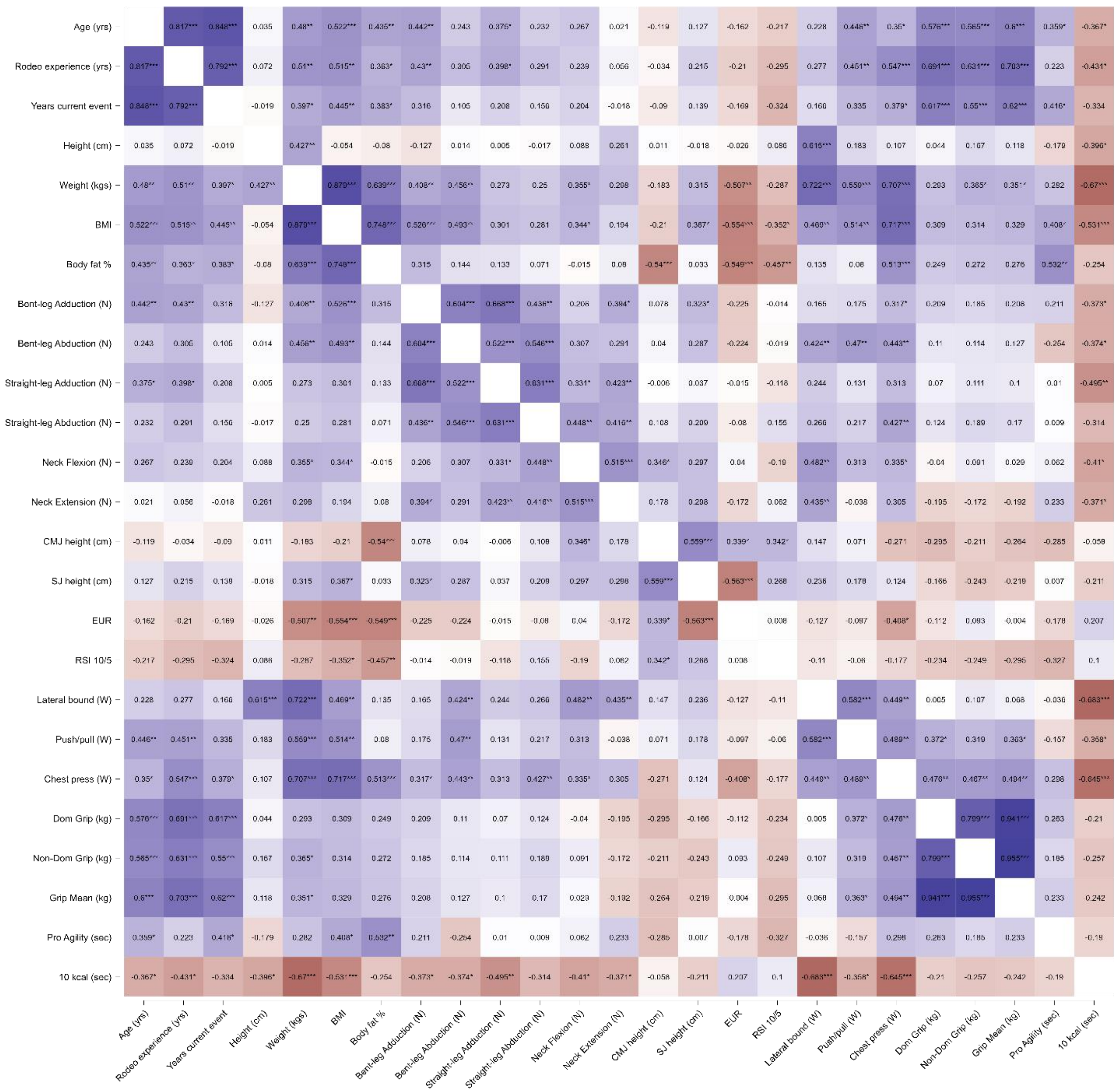


Supplementary Figure 1. Spearman's Rho correlation coefficient heatmap (Riders (n=32) only). Purple=positive correlations. Burgundy=negative correlations. *$p<0.05$, **$p<0.01$, ***$p<0.001$.



Supplementary Figure 2. Spearman's Rho correlation coefficient heatmap (Fighters (n=11) only). Purple=positive correlations. Burgundy=negative correlations. **p*<0.05, ***p*<0.01, ****p*<0.001.



Supplementary Figure 3. Pearson's *r* correlation coefficient heatmap (N=43). Purple=positive correlations. Burgundy=negative correlations. **p*<0.05, ***p*<0.01, ****p*<0.001.