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ORIGINAL RESEARCH

# The relationship between powerlifting performance and hand grip strength among female athletes

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**Abstract.** With the rising competitiveness in the sport of powerlifting, coaches and athletes are continually looking for better ways to measure progress to predict and improve performance. Many studies have evaluated the link between hand grip strength (HGS) and performance in other sports, and HGS has been a predictor of total body strength. The current study examined the relationship between HGS and powerlifting performance among experienced female powerlifters. HGS was compared to the 1RM of the squat (SQ), bench press (BP), deadlift (DL) and aggregate total. It was hypothesized that there would be a positive meaningful relationship between HGS and powerlifting performance. Thirty-one (n=31) female powerlifting participants (age 29±6.3 years, body mass 82.8±27.8 kg) with at least 3 months of powerlifting training experience were assessed for HGS and powerlifting performance measures. Hand grip strength was measured with a Jamar hydraulic hand dynamometer prior to a sanctioned powerlifting meet. Three trials of HGS were completed by the participants where each trial was separated by 1-minute rest period. The average of the two highest HGS scores were recorded for analysis. The powerlifting performance measures were assessed at a sanctioned powerlifting meet comprised of 1 repetition maximums (1RM) in three event lifts, the back squat (BS), bench press (BP) and deadlift (DL). The event 1RMs, aggregate total (AT), and HGS scores were then normalized to body mass (BM). The normalized event 1RMs and AT were then compared to the normalized HGS scores with Pearson correlation coefficients (r). The BS, DL and AT scores demonstrated moderately significant relationships (r=0.46, r=0.51, r=0.48) respectively with HGS ($p<0.05$). Bench press performance had a low (r=0.35), but significant association with HGS ($p<0.05$). The BS/BM, BP/BM, DL/BM and AT/BM demonstrated significant moderate-high relationships (r=0.55, r=0.52, r=0.66, r=0.61) respectively with HGS ($p<0.05$). Within the parameters of this study, female powerlifting performance appears to have a meaningful positive relationship with HGS.

**Keywords.** Back squat, bench press, deadlift, grip strength, dynamometer, powerlifting.

## Introduction

Lifting heavy objects and testing strength has been a popular, competitive culture for many years. Hundreds of years ago, before weights, lifting heavy stones was the ultimate sign of strength and is still used in strongman contests (Pratt, 2016). After weights were introduced, the sport of weightlifting, which focuses on the snatch and the clean and jerk, made an appearance in the 1896 Olympic Games (Weightlifting equipment and history - Olympic sport history, 2020). However, it wasn't until the 1950s and 1960s that interest in specifically testing the squat bench and deadlift grew. Initially coined "the odd lifts," that didn't make up strongman or weightlifting competitions, a new strength sport emerged, and powerlifting was born ("British Weightlifting," n.d.).

Then, the first official powerlifting championship, held by the Amateur Athletics Union, took place in 1965 (Ferland & Comtois, 2019). The sport of powerlifting tests maximal strength through three different events, the back squat (BS), bench press (BP) and deadlift (DL). During a meet, each athlete has three attempts, per event, to test their one rep maximum (1RM). The best of the three, completed

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lifts are then added together for the lifter's total. This total will be compared to other lifters of the same gender and weight class, and the highest total will win. Within powerlifting, there are two different divisions, raw and equipped. The raw division allows lifters to compete in knee sleeves, wrist wraps and a lifting belt, where equipped also allows knee wraps, squat suits, bench shirts and deadlift suits (Ferland & Comtois, 2019).

From then on, the sport of powerlifting grew at a steady pace, typically at male-dominant underground facilities and basement gymnasiums. During late 2000s, heavy barbell lifting became more socially accepted and popularity gained momentum with both men and women. Between 2014 and 2018, meet participation grew from 59,000 lifters to over 101,000 lifters, and the women competitors nearly doubled (Open Powerlifting, 2021). During this time, a shift in society on what it meant to be a fit, healthy woman occurred, and consequently, more females became interested in heavy lifting (Jackson & Marsh, 1986). So, as mainstream views on women in strength sports started to evolve over the last decade, female powerlifting started to grow at a massive rate and continues to do so today.

Although many studies have evaluated the link between hand grip strength (HGS) and sport performance, when focusing specifically on powerlifting, research on the relationship between handgrip strength and performance is limited. HGS has often been used as an indicator of strength (Cronin et al., 2017). Further, Schoffstall et al. (2010), suggested a strong correlation between HGS and powerlifting strength, observing men and women during the BS, BP, and DL. However, this study included a small sample size (n=17) with only 3 females included in the study. The authors also agreed that more data is needed to better examine this relationship.

Despite the growing popularity of females participating in powerlifting competitions, research is also still lacking regarding female physiology and performance. In general, females are underrepresented in sports studies, although there are known differences between males and females (Emmonds et al., 2019). Sport performance, height, weight, muscle mass, anaerobic threshold, body fat, and hormonal differences, have all been identified as potential differentiating factors between men and women (Thibault et al., 2010). For example, when looking at hormone changes during a menstrual cycle, it may have an impact on muscle strength trainability and physical performance, depending on the phase (Sung et al., 2014). Understanding this information and how it affects a female athlete can lead to more efficient training, recovery, and performance guidelines. In addition, gender equality in sports research may contribute to more positive attitudes towards women's sports. Although links between HGS and performance have been examined, it's important to reiterate that more research is needed specifically for women in powerlifting (Cronin et al., 2017). Collecting relevant data is a significant part of assessing athletes, their progress and performance levels. Many different tests are used to help predict and determine strength; however, as coaches usually find themselves lacking funds and resources, measuring HGS is efficient and accessible.

Powerlifting is focused on three fundamental exercises, the BS, BP, and DL; during each lift, the "power grip" is utilized. Cronin et al. (2017) defined this grip to be commonly incorporated when an individual places a cylindrical-shaped object, like a barbell, in the palm and the fingers form around the object. The hand then serves as the point of contact where forces are transferred, and because of this, HGS is significant for a successful lift. Further, we can expect the sport of powerlifting to require ample HGS. Koley & Yadav (2009) defined HGS as, "the result of the maximum force that the subject is able to exert under normal biokinetic conditions through the voluntary flexion of all finger joints, thumbs, and wrists." When comparing to other athletic groups, such as gymnasts, powerlifters have shown significantly higher HGS measurements (Ruprai et al., 2016). When compared to sedentary individuals, weightlifting athletes had higher HGS recordings in both dominant and non-dominant hands (Erdağı et al., 2020). From this evidence, it is reasonable to speculate that competitive powerlifters will possess higher HGS measurements when compared to non-athletes as well as some, other athletic groups.

Although research is limited surrounding HGS and strength sports, these activities require athletes to possess a high level of HGS, and there is some literature that suggests a strong linear relationship between maximal isometric HGS and the strength of an athlete (Schoffstall et al., 2010). For powerlifters, Schoffstall et al. (2010) reported nearly perfect correlations between HGS and raw powerlifting totals during a meet performance. The study involved 17 subjects, where grip strength was tested prior to a sanctioned competition involving the BS, BP and DL. Results showed these correlations between the raw and equipped group: 1RM BS (r=0.95) vs. (r=0.36), 1RM BP (r=0.98) vs. (r=0.31), 1RM DL (r=0.97) vs. (r=0.41), and AT (r=0.97) vs. (r=0.41). Although these results are promising, this study used a relatively

small sample size (n=7) raw competitors, only 3 of which were female.

Hand grip strength is suggested to be a predictor and variable of other sport performances in general. In combat sports, HGS has been a strong predictor for professional boxers and found to be higher among successful wrestlers (Guidetti et al., 2002; Nikooie et al., 2017). Similarly, among professional baseball players, correlations between HGS and home runs, total bases and slugging percentage have been documented (Hoffman et al., 2009).

In support of these relationships, HGS may be a good indicator of experience, also helping distinguish elite athletes apart from their sub-elite athlete counterparts. Studies have verified that elite athletes have greater HGS when compared to sub-elite athletes (Cronin et al., 2017). Within this literature, elite rock climbers, American football players, handball players, ice hockey players, male wrestlers and judokas, and female combat sport athletes were included. Research conducted by Fry et al. (2006) suggested HGS to be a variable among elite classification when observing male junior weightlifters. When comparing HGS performance assessments between elite and non-elite athletes, they recorded 52.5 ± 8.1 vs 42.2 ± 11.1 (kg), respectively. Cronin et al. (2017) also revealed HGS to be a characteristic of elite athletes and predicator of lower body strength, sprinting and jumping, lean muscle mass and training experience. In agreement with Erdağı et al. (2020) and considering the studies above, HGS may be a useful tool to predict performance, identify those who possess top performing characteristics and to recruit elite strength athletes. Moreover, it appears that possessing greater HGS may be beneficial to excel in certain sports.

As powerlifting has evolved over the last couple decades, athletes have become stronger and more competitive. Top performing competitors can lift a few times their bodyweight, and many world record holders could be claimed as some of the strongest individuals in the world. In 2002, Mike Booker recorded a 551-pound squat in the 132-weight class ("All-time raw powerlifting records released," n.d.). Ed Coan holds 71 world records in powerlifting and is known as the lightest person to pass a 2,400 total (Bio Edward, 2020). As records become more competitive, athletes and coaches are continually searching for ways to better assess development and predict performance. Knowing what tools are useful and accurate will always be of great interest to strength and performance professionals. Testing strength informs athletes and coaches on progress made from training, current levels of performance and allows for more specific goal setting in the future. It appears that HGS may be a useful tool to predict performance and possessing a greater HGS may lead to greater success. In many sports, HGS may be associated with an athlete's ability, and could be useful as an individual strives to reach an elite performance status. Including HGS testing in the sport of powerlifting may help distinguish elite athletes apart from their sub-elite counterparts.

Noting the aforementioned potential uses of knowledge related to HGS, there is currently a paucity of research regarding HGS and female athletes. As such, the current study investigated the relationship between HGS and powerlifting performance among female athletes.

## Methods

### Participants

Participants for this study included 30 female athletes competing at a United States Powerlifting Association (USPA) powerlifting meet in Salt Lake City, Utah. Ages ranged from 19 to 39, and athletes competed in the "Raw" powerlifting category. All participants were healthy and possessed more than 3 months lifting experience with the squat, bench press and deadlift, as they trained for this meet. They were recruited via email that was sent out to meet participants. Signage was also on-site at competition weigh-ins.

Prior to any assessment, permission from the Institutional Review Board was received. Each participant was given a consent form to read and sign. Detailed instructions were given before any testing was administered. It was made clear that athletes were allowed to withdraw from the study at any time and that participation was voluntary.

### Instruments and Apparatus

The powerlifting meet and weigh-ins were held at the Compound Gym, in Salt Lake City Utah. Equipment used during the meet included all USPA certified equipment including barbells, calibrated plates, combo racks. Equipment met safety standards and was provided from the federation as this was a sanctioned meet.

To measure hand HGS, a Jamar hydraulic hand dynamometer was used. This type of instrument has been claimed to be the "gold standard" when

measuring maximal isometric HGS (Gasior et al., 2018). The Jamar is also the most widely used hand grip dynamometer and has the most extensive normative data and concurrent validity ($r$ = 0.9998; $r$ > 0.96) (Roberts et al., 2011). Further, Bellace et al. (2000) demonstrated the Jamar to be highly reliable (ICC [3,1] = 0.98) and valid (ICC (2,K) = 0.99).

**Figure 1.** Jamar hydraulic hand dynamometer used for hand grip strength assessment.

### Procedures

The study took place over two days, with HGS testing on the first day, and the powerlifting meet on the second day. Each participant had their HGS assessed at the time of weigh ins. Body weight was recorded by a meet official. In the same private room, each volunteer had their HGS assessed. To increase consistency and reliability of the data collected, specific measurement protocols were followed. This included using the same positioning for all participants, handle position (second position), wrist (0-30 degrees of dorsiflexion), forearm (neutral), shoulder (adducted, naturally rotated) and elbow position (90 degrees of flexion), posture (seated), time intervals (3 measures), and which hand to use (dominant). Participants were asked to squeeze "as hard as they could in this position." Following instructions, subjects were given the opportunity to ask if they needed further explanation. Using only their dominant hand, each individual repeated the trial three times, with 1-minute rest intervals in between. A stopwatch was used to track rest times. Readings were recorded in kilograms before transferring to an electronic data base (i.e. MS Excel spreadsheet).

The USPA powerlifting competition took place the following morning. Thirty minutes prior to the sanctioned meet, an official conducted a rules meeting, which all lifters were required to attend. During this time, approved equipment and standards, rules of competition and rules of each lift were briefed. Each athlete had the same duration of time to warm up, and then had three attempts to achieve their 1RM BS, BP and DL (measured in kg). The highest successful lift from each volunteer's BS, BP, and DL was recorded by the meet director. Performance was measured by each event lift as well as the combined aggregate total (AT) of the 1RM of a BS, BP, and DL. Data for body mass, attempts for the BS, BP, and DL and AT were transferred from meet results in the aforementioned Excel spreadsheet.

### Design and Analysis

The variables gathered for analysis in this study included: body mass (BM; kgs), 1RM from each event lift, AT, as well as HGS. The 1RMs as well as total were compared to the athlete's average of the highest two HGS measurements with Pearson correlation coefficients (PCCS or r). The event 1RMs, AT, and average of the highest two HGS measurements were normalized to BM and were again compared with PCCs. The PCCS were considered meaningful/significant when $r \geq 0.40$ and $\alpha \leq 0.05$. The statistical analysis were conducted with MS Excel 2013 and were peer reviewed as suggested by Al Tarawneh at al. (2017).

An a priori power analysis was conducted with G*POWER 3.1.9.2 (Universitat Kiel, Germany) software (Faul et al., 2007). A participant sample size of n=30 was required to achieve: a medium-high effect size of ES=0.40 (Cohen, 1988), statistical power $1-\beta=0.75$ (one-tailed), and $\alpha=0.05$. The sample size examined in the current study consisted of n=30 female powerlifters.

## Results

Thirty-one female participants completed the study. The average age and BM were 28.9±5.5 years and 83.1±28.2 kg respectively (Table 1). The event 1RMs and AT are presented in Table 2 with normalized values in Table 3. Table 4 lists the HGS trial score, average of the two highest HGS trial scores, and average of the two highest HGS trial scores as normalized to BM.

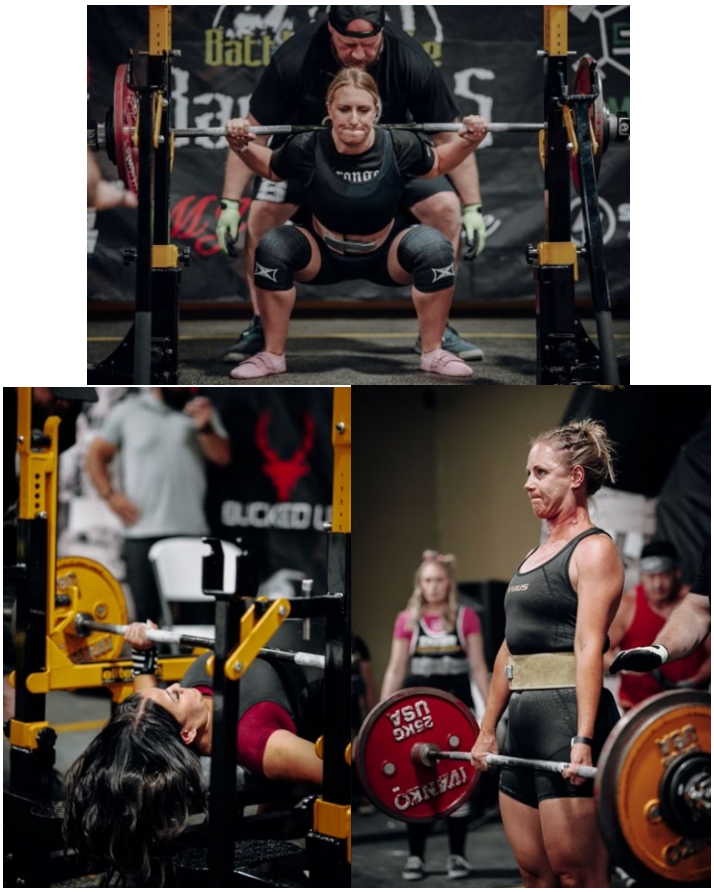

**Figure 2.** Squat, bench press and deadlift events for the powerlifting competition held in Salt Lake City, Utah, US. Pictures courtesy of Strong Shots Strength Photography and with permission of those pictured.

**Table 1**
Participants' descriptive information (Mean±SD).

| | Age (years) | Mass (kg) |
|---|---|---|
| Female (n=30) | 28.9±5.5 | 83.1±28.2 |

**Table 2**
Competition event lifts Kgs (Mean±SD).

| | Squat | Bench Press | Deadlift | Total |
|---|---|---|---|---|
| Female (n=30) | 115.3±34.0 | 66.9±19.1 | 141.5±33.0 | 323.8±81.4 |

**Table 3**
Competition event lifts Kgs/body mass Kgs (Mean±SD).

| | Squat/BM | Bench Press/BM | Deadlift/BM | Total/BM |
|---|---|---|---|---|
| Female (n=30) | 1.5±0.4 | 0.9±0.3 | 1.8±0.5 | 4.1±1.2 |

**Table 4**
HGS Trial Data (kg)

| | Trial 1 | Trial 2 | Trial 3 | Highest Two Trials Mean | Highest Two Trials Mean/Body Mass |
|---|---|---|---|---|---|
| Female (n=30) | 31.7±7.3 | 30.4±7.6 | 31.2±7.2 | 32.0±7.1 | 0.4±0.1 |

**Mean two highest trials; Mean±SD.*

**Table 5**
Measured HGS compared to reference values.

| Participant | Age | Highest Two Trials Mean HGS (kg) | Normative Percentile Range (Actual) |
|---|---|---|---|
| 1 | 19 | 30 | 50-<75 |
| 2* | 23 | 46.5 | 90-<100 |
| 3 | 20 | 37.5 | 75-<90 |
| 4 | 19 | 30 | 50-<75 |
| 5 | 32 | 26 | 25-<50 |
| 6 | 31 | 23.5 | 10-<25 |
| 7 | 29 | 24 | 25-<50 |
| 8 | 34 | 27 | 25-<50 |
| 9 | 31 | 32.5 | 50-<75 |
| 10 | 33 | 29.5 | 25-<50 |
| 11 | 28 | 32 | 50-<75 |
| 12 | 31 | 49 | 90-<100 |
| 13 | 23 | 36.5 | 75-<90 |
| 15 | 24 | 26 | 25-<50 |
| 16 | 33 | 22.5 | 10-<25 |
| 17 | 34 | 31.5 | 50-<75 |
| 18 | 31 | 31 | 50-<75 |
| 19 | 27 | 39 | 75-<90 |
| 20* | 30 | 38.5 | 90-<100 |
| 21 | 35 | 39 | 90-<100 |
| 22 | 27 | 38 | 75-<90 |
| 23 | 21 | 30.5 | 50-<75 |
| 24 | 25 | 43.5 | 90-<100 |
| 25 | 26 | 26.5 | 25-<50 |
| 26 | 32 | 20.5 | 10-<25 |
| 27 | 29 | 34 | 75-<90 |
| 28 | 38 | 25.5 | 25-<50 |
| 29 | 37 | 31.5 | 50-<75 |
| 30* | 39 | 24.5 | 25-<50 |
| 31 | 27 | 33.5 | 50-<75 |

**Indicates best lifter awards in the meet. Normative reference percentiles were obtained from Table 1 (Wang et al., 2018) and are based on sex and age. For example, Participant 1's HGS measures between the 50$^{th}$ and 75$^{th}$ percentile of all 18–24-year-old women in the United States.*

**Table 6**
Comparison of Event Lifts and HGS.

| Event | *HGS* *r* | Significant? P<0.05 | Size |
|---|---|---|---|
| Back Squat | 0.46 | Yes | Moderate |
| Bench Press | 0.35 | Yes | Low |
| Deadlift | 0.51 | Yes | Moderate |
| Event Total | 0.48 | Yes | Moderate |

**Table 7**
Comparison of event lifts/body mass and HGS/body mass.

| Event | *HGS/BM* *r* | Significant? P<0.05 | Size |
|---|---|---|---|
| Back Squat/BM | 0.55 | Yes | Moderate |
| Bench Press/BM | 0.52 | Yes | Moderate |
| Deadlift/BM | 0.66 | Yes | Moderate/High |
| Event Total/BM | 0.61 | Yes | Moderate/High |

Table 5 presents the individual lifter's HGS as compared to population normative values. Twenty (19) participants scored at or above the 50th percentile of normative reference values for HGS (see table 5). Two of these participants were awarded "best lifter" for powerlifting meet performance.

The results of the PCC's (r) suggested a moderate significant relationship between HGS and BS, DL and AT scores ($p<0.05$) (see Table 6). There was a low, but significant relationship between HGS and BP performance ($p<0.05$). Results also suggested significant moderate-high relationships between HGS/BM and: BS/BM, BP/BM, DL/BM and AT/BM ($p<0.05$) (see Table 7).

## Discussion

The purpose of this study was to determine if a meaningful relationship existed between female powerlifting performance and HGS. It was hypothesized that powerlifting performance would have a significant meaningful relationship with HGS. The study results revealed that 1RM BS, 1RM BP, 1RM DL and AT performance had a moderately significant relationship with HGS (r=0.35-0.51). Although there was a comparatively lower relationship between BP 1-RM performance and HGS, it was still considered a significant relationship. Study results also demonstrated significant moderate-high relationships between HGS as normalized to BM and: 1RM BS/BM, 1RM BP/BM, 1RM DL/BM and AT/BM (r=0.52-0.66).

The majority of participants in the study (63%) demonstrated HGS recordings above normative reference 50th percentiles (Wang et. al, 2018). Within this 63%, two of these participants were awarded "best lifter" for powerlifting meet performance, and 5 of these participants were above the normative reference 90th percentiles. It was expected that the participants in the current study would have high HGS measurements as previous literature has previously documented a strong positive linear relationship between HGS and maximal upper and lower body strength (Cronin et al., 2017). Studies also have shown powerlifters to possess significantly higher HGS ($p<0.0001$) when compared gymnasts and untrained individuals (Ruprai et al., 2016). With comparatively high HGS recorded among the powerlifting participants in the current study, it is possible that powerlifting is an inherently good training program for improving HGS. This is a significant finding, as it may benefit the general and aging population's overall health and functional abilities. Studies have confirmed a positive relationship between HGS, total body muscular strength and functional ability among aging adults (DeBeliso et al., 2015a; DeBeliso et al., 2015b). Maintaining or improving muscular strength and power is important as a person ages. The authors (DeBeliso et al., 2015a; DeBeliso et al., 2015b) discussed how the loss of muscular strength and power can impact the ability to perform activities of daily living (i.e. walking, climbing stairs, sitting, standing, etc.). Among healthy 45- to 68-year-old men, Rantanen et al. (1999), found HGS to be a strong predictor of disabilities later in life. Specifically, those with the lowest HGS tests were less likely to complete daily activities, including walking fast, completing heavy housework, rising from a chair, dressing, bathing, eating, and lifting more than 4.5 kg. Among female participants over the age of 60, Alonso et al. (2018) concluded that a weaker HGS can point to certain diseases later in life. Likewise, the Alonso et al., study demonstrated that lower HGS measurements were correlated with lower scores in dynamic postural balance and time up and go tests, suggesting that HGS is significantly related to lower limb strength in older women. From the preceding data, it also appears that obtaining valid and reliable HGS measurements can give an objective index of strength and may serve as a screening instrument during annual physical exams as previously suggested (DeBeliso et al., 2015a; DeBeliso et al., 2015b; Bahannon, 2019).

The current study chose to assess powerlifters specifically competing in the raw and not equipped category. Previous research from Schoffstall et al. (2010) already displayed a stronger HGS from male raw lifters when compared to equipped male lifters. The PCCS of HGS to the event 1RMs and AT for raw powerlifters were extremely high (r≥0.95) while equipped powerlifters were low-moderate (r=0.31-0.41). When wearing wraps, suits, bench shirts and deadlift suits, we can expect additional support during training that may not transfer to better HGS. Conversely, without supportive gear, demands of HGS are likely increased during lift events and training. Our decision to only include the raw category, was to allow a greater examination of strength and a more direct relationship not confounded by supportive equipment. The current study also chose to assess female athletes only, as research is sparse in this strength sport and sports in general. Emmonds et al. (2019) observed a lack of sport science research, inclusive of experienced female athletes. Without sufficient research, this limits the ability to follow an evidence-based approach when working with female athletes. Often, performance strategies are based on evidence derived from research that focused on male athletes (Emmonds et al. 2019). According to Emmonds et al. (2019), there are scenarios where research from male athletes may have limited application to female athletes. As we strive for greater gender representation in sport research, we were specifically interested in the relationship between HGS and female powerlifting performance. A pertinent result of the current study was to contrast the 1RM BS and 1RM BP with Collegiate female norms. The powerlifter average 1RM for the BS and the BP would rank above the 90$^{th}$ %ile for female Collegiate: Volleyball players, Swimmers, Basketball players, and Softball players (Hoffman, 2016).

A relationship between HGS and various sport performances have already been established. Koley et al. (2009) suggested that HGS may be a good indicator for higher performance in cricket. Previous evidence from Guidetti et al. (2002) found HGS to be a strong predictor for professional boxers. Niookie et al. (2017) observed higher HGS values among successful wrestlers and Tan et al. (2001) suggested a significant association between HGS and bowling. When comparing elite athletes to sub-elite athletes, Cronin et al. (2017) observed elite athletes to possess a higher HGS when compared to their sub-elite counterparts. This evidence suggests that HGS could be an indicator to distinguish between elite and sub-elite athletes in various sports, including rock climbers, American football players, handball players, ice hockey players, male wrestlers and judokas, and female combat sport athletes.

Within the parameters of this study, HGS proved to be related to all three powerlifting event 1RM lifts and AT. We found it surprising that all lift events proved to have moderate or moderate-high relationships with HGS, noting the lowest relationship was between HGS and BP performance (when not normalized to BM). A weak relationship between 1RM BP and HGS has been shown among older adults and breast cancer survivors (Milliken et al., 2008; Rogers et al., 2017). A 1RM BP is considered a multi-joint, dynamic constant external resistance exercise, involving multiple large muscle groups to execute. Conversely, HGS as assessed in the current study is an isometric exercise, using smaller muscle groups to perform. Such differences may contribute to findings; however, the current study results are relevant.

Another possible scenario to explain the higher relationship between HGS and the 1RM BQ and 1RM DL may have to do with hand-bar coupling factors. Initially, the DL requires the lifter to couple with the bar in a fashion that requires that the bar be firmly secured with what is likely a maximal crushing grip effort, then later turns into an effort of preventing the bar from becoming unsecure from the hand or break-away grip strength. The effort required to execute the DL repeatedly over time (i.e. multiple RT programs of 8-12 weeks in duration) likely leads to elevated HGS and the moderate-high relationship with DL strength. The 1RM DL and 1RM BS are typically highly correlated, for example in the current study, PCC between the 1/RM BS/BM and 1RM DL/BM is r=0.92. As such, it is understandable as to why a moderate PCC between HGS and the 1RM BS would exist. A maximal crushing hand grip with the bar is not necessary to execute the BS or BP. In fact, many powerlifters use an open hand grip during the execution of the BP and the BS. With that said, the aforementioned may be an explanation as to why the relationship between the 1RM DL and HGS was slightly higher than that exhibited between the 1RM BP and HGS, as well as the 1RM BS and HGS.

The main limitation of this study was sample size. Powerlifting meets will limit the number of participants, and will include a variety of ages, categories, and weight classes. If more participants were close in age, weight, and experience levels, then relationships between powerlifting performance and HGS might be further clarified. A second limitation of this study involves those who are cutting weight to be in a more competitive weight class. Prevalence of rapid weight loss for competitive powerlifting

competition is high, with about 85% among male and female powerlifters self-reporting to cut weight for competition (Nolan et al., 2020). Assuming some of the participants were in a dehydrated state, it could have affected their performance when performing HGS measures at the time of weigh-ins. Finally, although individuals under the age of 19 were competing, they were asked not to participate in the study.

Future research should take the aforementioned limitations into consideration. With the growing interest in junior powerlifting, it may be worth including a younger population (<19 years of age) in future studies in order to confirm the importance of HGS as a predictor of strength among adolescent powerlifters. The results of such research could inform coaches and athletes strategize their resistance training to optimize lifting performance while on the competitive platform. Finally, an alternate instrument to assess HGS grip strength such as the GripForce Map system might provide the specificity and resolution required to identify what aspects of HGS might play a greater role in powerlifting performance (DeBeliso et al., 2013).

In conclusion, this study indicates a moderate to high relationship between HGS and female powerlifting performance when normalized to BM. This is the first study to examine the association between HGS and strength among female powerlifters only. A novel finding was that all three powerlifting lift events (SQ, BP, DL) and AT have shown a significant, positive meaningful relationship with HGS. It appears that HGS can be a useful, easily accessible tool to predict total body strength and potentially predict athlete classification. The findings of this study may assist strength professionals when working with athletes or recruiting female lifters with regards to the development and usefulness of HGS.

### Conflict of Interest Declaration

No funding was received for this research. The authors have no conflict of interest related to this research. This research has not been previously published.

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