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The National Football League-225 Bench Press Test and the Size-Weight Illusion

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Keywords

Muscular strength, muscular endurance, athlete, performance testing, visual perception

Introduction

The size-weight illusion (SWI) is a perceptual phenomenon that occurs when a person estimates that a large object feels lighter compared to a smaller object of equal weight. **This has been demonstrated in research utilizing objects with a range of weights, from 25g (Stevens and Rubin, 1970) up to 24 kg (Luczak & Ge, 1989).** This illusion is contrary to the expectations of most people. Due to prior experiences, most individuals will expect a larger object to be heavier than a smaller object. It is these expectations that are thought to cause the SWI, with the prevalent theory suggesting that lifters' experience of an object's heaviness reflects a contrast to their expectations, rather than the actual mass of the object (Buckingham & Goodale, 2010; Buckingham & MacDonald, 2016; Flanagan, Bittner, & Johansson, 2008).

Although the SWI is well-studied in the laboratory (Buckingham, 2014; Ellis & Lederman, 1993), it is not a well-known effect amongst the general public. However, **it is intuitive for lay-people to expect that size and weight might be related.** In weightlifting, weight plates are generally standardized in approximate size for a particular weight. In the United States, typical diameters for 20.4 kg (45 lb), 11.3 kg (25 lb), and 4.5 kg (10 lb) weight plates are 45.7 cm (18 in), 30.4 cm (12 in), and 22.8 cm (9 in) respectively. This standardization in size and weight is very familiar to an experienced weightlifter. Often, when a relatively heavy weight is being lifted, the combination of weight plates utilized is that which requires the fewest number of plates to be loaded onto the barbell. Therefore, larger plates are used when possible rather than a greater number of smaller diameter, lighter plates. However, **weight-lifters sometimes attempt to exploit their own expectations about the relationship between size and weight** to break through a lifting plateau or successfully complete a difficult set of repetitions. For instance, a typical 102.27 kg (225 lb) bench press will be set up with two 45 lb

weight plates loaded on each side of a standard Olympic 20.4 kg (45 lb) barbell. However, 225 lb may be an intimidating lift for some, particularly if that amount is near a lifter's one-repetition maximum (1RM) or when it is used in a high-repetition set. A strategy sometimes used by weightlifters in situations such as this is to change the plate arrangement by substituting smaller weight plates for some of the larger ones, potentially giving the barbell configuration an appearance of being lighter. An adjustment in this example is to substitute one of the 45 lb plates on each side of the barbell with one 25 lb plate and two 10 lb plates. The total load remains 225 lb, but it is hoped that the use of smaller plates will cause the load to be perceived by the lifter as lighter, and therefore, be easier to lift (e.g., "Change the plates around," 2015). While this strategy is not uncommon, the success of its implementation is unclear, as no scientific research to date has assessed its validity.

Almost all research on the SWI to date suggests that apparent size has no long-term effect on lifting performance. Buckingham et al. (2014) demonstrated that the SWI did not affect weightlifting performance during a repetition lifting test utilizing a 2.27 kg (5 lb) dumbbell. However, due to the relative lightness of the weight utilized, this research may not be translatable to a lifting task that is nearer one's maximal lifting capabilities. Additionally, the "untrained" status of the participants utilized limits its applicability to experienced weightlifters. Furthermore, lab-based work by Flanagan and Beltzner (2000) indicates that when one lifts illusion-inducing objects repeatedly, the sensorimotor system adjusts to the actual weight of the object and in turn applies the correct force, even if the lifter believes that the object's weight is different than it actually is. In other words, after a few repetitions, one's body responds appropriately to the lifting task, regardless of one's perception

(Grandy & Westwood, 2006). Therefore, **despite the anecdotal belief by weightlifters that plate configuration will improve their performance, there is no empirical evidence to suggest it would.**

The purpose of this study was to directly test the anecdotal reports that the size and arrangement of weight plates on a bar can affect weightlifting performance. To this end, experienced, weight-trained collegiate American football players performed three repetitions-to-fatigue bench press tests, with different weight plate arrangements**. A real-world training environment, which included the National Football League's 225 lb repetition bench press test (NFL-225) was utilized. This test consists of bench-pressing a weight of 225 lb for as many repetitions as possible in one set. Many collegiate American football teams incorporate the NFL-225 into their training at specific points in the program (Mann, Ivey, Stoner, Mayhew, & Brechue, 2015; Mann, Ivey, Brechue, & Mayhew, 2014; Mayhew et al., 2002).** This test is a component of the NFL Scouting Combine testing battery (Mann, Stoner, & Mayhew, 2012; Mayhew et al., 2002; Robbins, 2012), which is a series of fitness tests used to help determine a collegiate American football player's potential for success in the NFL.

The NFL-225 uses a standard weight [102.27 kg (225 lb)] regardless of the strength of the athlete. Therefore, players who have a higher 1RM bench press are likely to perform better than those with a lower 1RM, due to their strength levels relative to the test load being higher. That is, the 225 lb testing weight represents a smaller percentage of their 1RM (i.e., 1RM/225).

In the present investigation, two of the three bench press tests featured equal loads of 225 lb, but different weight plate arrangements. The third test had the appearance of

having a 225 lb load, but the load was actually less. Based on the work of Flanagan and Beltzner (2000), Grandy and Westwood (2006), and Buckingham et al. (2014), **and contrary to anecdotal reports,** it was hypothesized that the manipulations would not have any effect on the total number of repetitions completed by the participants during bench press testing sessions of equal load, regardless of their strength relative to the tests.

Methods

Experimental Approach

To examine how manipulations of plate size and arrangement affect weightlifting performance, the current investigation employed a counterbalanced crossover design. Over the course of three weeks, participants completed three different bench press repetitions-to-fatigue tests. The barbell and weight plate arrangements for each of the three tests had the appearance of their total load being 225 lb. Two of the arrangements did total 225 lb, although the weight plates used to achieve the load of 225 lb were different [NFL-225 and SWI-225 (descriptions below)]. These two arrangements allowed direct testing for a SWI effect. The third arrangement, although having the appearance of being 225 lb, weighed only 215 lb (97.72 kg) [SWI-215 (description below)]. This configuration allowed further exploration of the SWI. If participants' perception of a barbell load did have an effect on performance, then the 225 lb appearance of the SWI-215 barbell configuration would limit the number of repetitions to a similar number as achieved during the NFL- and SWI-225 tests, despite the load actually being less.

While the difference between the two 225 lb barbell configurations (NFL-225 and SWI-225) was easily discernable to the participants, they were kept unaware that the 215 lb configuration (SWI-215) differed in actual weight, even though it appeared identical to the NFL-

225 configuration. Participants also completed a bench press one-repetition maximum test (1RM) in the week following the final bench press repetition-to-fatigue test. These values were used to determine players' strength relative to the 225 lb bench press.

Participants

Participants were recruited from a National Collegiate Athletic Association (NCAA) Division II American football team. This program was a part of the Intercollegiate Athletics Department at a Midwestern regional university. The coaching staff of the team agreed to the recruitment of participants from the team as well as allowing the bench press repetition testing sessions to be added into the strength and conditioning program. Select details of the study were verbally explained to team members by the principle investigator prior to the initiation of the investigation. Volunteers signed an informed consent document. The study began with 80 participants and complete data was collected for 72 of those participants (19.9 ± 1.3 years old, 102.3 ± 19.4 kg, and 7.6 ± 1.5 years of weight training experience). The experiment occurred over the final five weeks of the winter off-season training program during the spring academic term.

In order to limit potentially influencing the outcome of the three tests, participants were not informed that the purpose of the repetitions-to-fatigue tests was to examine the effect of weight plate size and arrangement on performance. Rather, they were told that the tests' results were going to be used to: 1) examine the effects of a strength and power training program on muscular endurance, and to 2) test the validity of a NFL-225 1RM prediction formula. In addition to the SWI purpose being withheld, participants were not told that one of the repetition tests that they would undertake would be completed using a total barbell load of only 215 lb. This investigation, including the incomplete disclosure and deception, was approved by the

university's Institutional Review Board. Upon conclusion of the study, participants were debriefed by the primary investigator at a team meeting. The true purpose of the investigation was explained to them at this point, and participants were given an opportunity to ask questions and have them answered.

The NFL-225, SWI-225, and SWI-215 bench press tests

Three different bench press repetitions-to-fatigue tests were utilized in this study. The barbell load for all three test conditions had the appearance of weighing 225 lb. Two of the tests had an actual load of 225 lb, and were differentiated by weight plate size and arrangement. One test had a load of only 215 lb, but had the appearance of weighing 225 lb (Figure 1).

1) **NFL-225:** A total barbell load of 225 lb, set up with a standard weight plate arrangement for a NFL-225 test – a 45 lb Olympic barbell, with two, 45 lb plates loaded on each side.
2) **SWI-225:** A total barbell load of 225 lb, set up with an alternate arrangement of weight plates – a 45 lb Olympic barbell, with one 45 lb plate, one 25 lb plate, and two 10 lb plates on each side.
3) **SWI-215:** A total barbell load of 215 lb, which had the appearance of the NFL-225. While this set up appeared to have two 45 lb plates on each side of the barbell, one of those two plates had a weight of only 40 lb, but was visually indistinguishable from the accompanying 45 lb plate.
    a. The 40 lb plates were created by modifying 45 lb plates. To reduce their weight to only 40 lb, 0.254 cm (0.10 in) was removed from the back (flat) side of 45 lb plates, which equated to approximately 5 lb. The back sides were then repainted to match the front, and then scuffed to give an appearance of use and age. Since the front side of the plate was not altered, the 45 lb markings/labels remained.

These plates were indistinguishable from standard 45 lb plates without close inspection and the 10 lb discrepancy between the SWI-215 and the two 225 lb tests was small enough that participants did not notice the difference when holding the loaded barbell in the lifting position.

(Figure 1 about here)

Data Collection

The experiment was conducted during the final five weeks of the team's **eight week** off-season strength and condition program**, which had a focus on increasing the athletes' strength and power.** At the end of Week 1 of the study, all players completed a NFL-225 test for purposes of familiarization. Data collection for the bench press repetitions-to-fatigue tests were conducted **upon completion of the regular** training session, on the final day of the week, across Weeks 2, 3, and 4**. The training session on these days largely focused on power production and were similar across the three weeks. As with every other training session, all athletes completed the same workouts on these days. Finally,** all players completed a 1RM bench press test (McGuigan, 2016) on the second day of Week 5, after four days of complete rest (Table 1).

(Table 1 about here)

A counterbalanced crossover design was utilized. The three barbell configurations were grouped into three different Testing Orders (A, B, and C), each of which was incorporated into each of the three data collection sessions. **This design was employed to help control for any**

testing order effect as well as any weekly workout variability which may have influenced the testing sessions (Table 2).

Nine weightlifting stations were utilized for data collection. This allowed for three stations for each of the three Testing Orders each week (i.e., A x 3, B x 3, and C x 3). Each Testing Order group was populated with approximately the same number of participants (Table 2). Players tested at the same station each week. The arrangement of the three bench press tests among the stations was fashioned so that the three different barbell configurations were not grouped together in proximity, but rather alternated among stations (Table 1).

(Table 2 about here)

Testing procedures

Repetitions-to-fatigue bench press tests. The bench press testing stations (i.e., NFL-225, SWI-225, and SWI-215) were set up prior to the beginning of the workouts on the respective testing days by the principal investigator. The bench press barbell arrangements at each station were clearly visible to all members of the team throughout the workouts and were not used until the bench press tests, which occurred after the conclusion of the workout sessions.

For each of these tests, players were encouraged to use the same hand placement on the barbell as a 1RM bench press test, and were required to maintain a 5-point contact position throughout (Caulfield & Berninger, 2016). For a successful repetition, the bar had to touch the chest and return to a fully-extended arm position. There were no formal instructions for the pace of repetitions, however, most players self-selected a "touch-and-go" cadence**. Repetitions were counted by the football coaching staff and the primary investigator.** The test was complete when the participant could no longer successfully perform a repetition**. Since these tests were**

done in a competitive, but supportive team environment, there was a high amount of verbal encouragement from teammates and coaches throughout each of the testing sessions.

One-repetition Maximum (1RM) bench press test. **A 1RM is the maximum amount of weight that can be successfully lifted with correct technique for only one repetition. Participants completed two warm-up sets: 1) ten repetitions utilizing approximately 40% of their estimated 1RM followed by 2) five repetitions utilizing approximately 60% of their estimated 1RM. Following adequate rest, players loaded the barbell with approximately 80-85% of their estimated 1RM and completed one repetition. For each subsequent one-repetition set, weight was added until the athlete could no longer complete a repetition correctly. The 1RM was determined as the last weight utilized in which the participant successfully completed the lift with proper form through the entire range of motion (McGuigan, 2016).**

Statistical Analysis

A multiple linear regression was calculated using **IBM SPSS Statistics 24** (SPSS Inc., Chicago, Illinois, USA) to examine the association between participants' strength relative to load (expressed as the load ratio of the participants' 1RM divided by 225) and their repetitions for the NFL-225, the SWI-225, and the SWI-215. **The regression was followed up with a mixed design ANOVA to examine the relationships between relative strength and test condition. The level of significance for all analyses was set at .05.**

Results

A significant regression equation was found ($F(3,68) = 92.090$, $p < .001$), with an R^2 of .802. **The regression equation was 1.053 + .018 (NFL-225) - .001 (SWI-225) + .014 (SWI-215). The relationship between relative strength and repetitions was significant for the NFL-225 and SWI-215 test conditions. The relationship between relative strength and repetitions for the SWI-225 test condition was not significant.**

To further explore these findings, **IBM SPSS Statistics 24** (SPSS Inc., Chicago, Illinois, USA) was used to group participants into quartiles based on their strength relative to the test (computed as their 1RM divided by 225 with Quartile 1=highest strength relative to test load, Quartile 4=lowest strength relative to test load).

Strength Relative to Test Load = 1RM/225

A mixed-design ANOVA was then conducted to examine the relationship between quartiles and test condition on repetitions. This revealed a significant test condition x quartile interaction ($F(6, 136) = 3.40$, $p = .004$, $\eta^2 = .130$). Performance variables for each quartile can be found in Table 3. The interaction between test condition and quartile is illustrated in the plot in Figure 2.

(Table 3 about here)

(Figure 2 about here)

To explore the significant interaction, Bonferroni-corrected pairwise comparisons were conducted across the test conditions within each quartile. These comparisons revealed that for

Quartiles 1, 2, and 3 there was no significant difference between the NFL-225 and SWI-225 conditions (all p values > 0.05). However, participants in Quartile 4 (those with the lowest strength relative to test load) completed more repetitions for the SWI-225 compared to the NFL-225 (mean difference 1.176, standard error = .439, $p = 0.049$). Pairwise comparisons also indicated that participants in the second quartile completed more repetitions for the SWI-215 than they did for the NFL-225 ($p = 0.032$) or the SWI-225 ($p = 0.008$). Participants in the third quartile exhibited the same pattern, completing more repetitions for the SWI-215 than they did for the NFL-225 ($p = 0.002$) or the SWI-225 ($p < 0.001$).

Discussion

This study was designed to investigate the anecdotal notion, popular among weightlifters, that the size and arrangement of weights can affect weightlifting performance. Based on past research, it was hypothesized that the manipulations would not have any effect on the total number of repetitions completed by the participants during bench press testing sessions of equal load, regardless of their strength relative to the tests. The multiple regression results revealed that there was a significant relationship between the strength of the participant and repetitions achieved for the NFL-225 and SWI-215 test conditions but not for the SWI-225 test condition. This finding suggested a possible SWI effect for the SWI-225 test condition. To explore that possibility, the regression was followed up by the mixed-design ANOVA that revealed a significant interaction between quartiles and test condition.

For the majority of participants, weight plate configuration had no effect on their performance. Participants in the fourth quartile (those with the lowest strength relative to the

test load), however, completed more repetitions with the SWI-225 than with the NFL-225. Moreover, there was no difference for the SWI-215 performance relative to the other two testing barbell configurations for this group. This finding contrasts Buckingham et al. (2014) who demonstrated that a SWI induced by utilizing dumbbells of equal weight but of different size, had no effect on repetitions to fatigue in bicep curl performance. However, the present study and the Buckingham et al. (2014) investigation do have dissimilarities that may account for this discrepancy and do not allow them to be directly comparable. These include the use of experienced weightlifters vs. untrained lifters and utilizing a lifting load nearer maximal relative weight (102.27 kg) vs. a submaximal weight (2.27 kg).

In addition, the current investigation utilized three different testing configurations which were performed across three weeks. Therefore, a counterbalanced crossover design was employed in which three different Testing Orders were used to help control for any **testing order effect** and/or workout variability that may have influenced any of the data collection sessions. However, it should be noted that as the athletes were categorized into quartiles based on their 1RM relative to 225 lb **in a post-hoc fashion,** the Testing Orders were not equally distributed among some groups, particularly for the participants in Quartile 4 (Table 4). The majority of these players were members of Testing Order B, which completed the SWI-225 in the final data collection session. **Therefore, while the increase in repetitions that participants in the fourth quartile achieved during the SWI-225 test condition may have been due to a SWI effect, the increase could also have been caused a test order effect, or even a combination of both.**

(Table 4 about here)

For Quartiles 3 and 2, there were no differences between the NFL-225 and the SWI-225, but more repetitions were performed with the SWI-215. The differences in plate sizes and arrangements between the two 225 lb configurations apparently did not affect the performance of the participants. Additionally, these participants were able to complete more repetitions with the SWI-215 configuration despite it having an identical appearance to the NFL-225. This finding supports the work of Flanagan and Beltzner (2000), and Grandy and Westwood (2006), who have both demonstrated that with repeated repetitions, the sensorimotor complex adjusts itself appropriately to the actual demands of the task, regardless of the lifter's perception of that demand. For these two quartiles, it seems likely that the sensorimotor systems and the perceptual systems were operating independently of one another. In other words, even though participants thought they were lifting 225 lb, their sensorimotor system responded appropriately to the actual weight of 215 lb, thus resulting in the increased repetition performance. Regarding the Testing Order counterbalance of these two quartiles, participants in these groups were more equally distributed between Testing Orders A and C (Table 4). Quartile 3 had more participants in Testing Order A, which included the SWI-215 in the final week, which was also the test in which this group experienced the highest number of repetitions. It is not possible to determine from this study whether the difference in repetitions between test conditions was due to a **testing order** effect or simply the lighter load of the SWI-215, but both should be considered. Quartile 2 had more members in Testing Order C, which had the NFL-225 test as the final session. However, this group did not perform the most repetitions during this test, but rather during the SWI-215, which occurred in the previous week. A **testing order** effect was likely not a factor in the overall

performance of this group, which lends further support to the independent operation of the perceptual and sensory motor systems (Flanagan & Beltzner, 2000; Grandy & Westwood, 2006).

Quartile 1 (those with the highest strength relative to testing load) performed equally among the three bench press tests. They did not complete more repetitions with the SWI-215 compared to either of the two versions of the 225 lb barbell configuration. This appears to contradict the concept discussed above, that the sensorimotor and perceptual systems work independently of one another (Flanagan & Beltzner, 2000; Grandy & Westwood, 2006). According to that model, this quartile should have demonstrated similar results as Quartiles 2 and 3, in that more repetitions be completed during the SWI-215 test session. One possibility to consider for this discrepancy is the relative load for Quartile 1. Although all quartiles experienced a 10 lb load reduction with the SWI-215, for **those in the first** quartile it was a smaller load reduction relative to their higher 1RMs. It is possible that this relatively smaller load reduction was not large enough to elicit additional repetitions. If so, the repetitions for each of the three bench press tests were not completely representative of either the sensorimotor or perceptual systems, as demonstrated by both the Flanagan and Beltzner (2000) and Grandy and Westwood (2006) investigations. Regarding the counterbalance, the testing order held up very well for this quartile, with nearly equal distribution of the members across the three testing groups (Table 4).

Limitations and Future Research

The possible SWI effect observed in Quartile 4 was contrary to our hypothesis. As the first empirical investigation of the SWI in this context, this result is interesting. However, it is potentially confounded by a test order effect. As previously described, the testing order was counterbalanced to control for any test order effects and also any weekly variations in the workouts. While the groups were counterbalanced for the regression analysis, that balance was compromised after the creation of quartiles, particularly in the fourth quartile. Future research should consider designs in which the quartiles are created *a priori*, and are then counterbalanced accordingly to provide more control.

The current investigation suggests that **for most collegiate Division II American football players,** variations of the weight plate size and arrangement do not induce a SWI effect and do not appear to affect the performance of repetitions-to-fatigue bench press tests. This **seems to** be particularly true for those whom the weight used during the test is low relative to their 1RM bench press (e.g., Quartile 1). However, the influence of the SWI among those who perform repetition tests with a weight that is nearer their 1RM bench press (e.g., Quartile 4) is less clear. Further research **should attempt to clarify** any associations that may exist between the SWI and this population.

The weight plate arrangement that was utilized to investigate the SWI in the present study (i.e., SWI-225, Figure 1) is only one possible combination. Work by Amazeen (2014) indicates that changing the width of an object may have more of an influence on the magnitude of the SWI a lifter experiences than does changing the height. Examining variations in weight plate arrangements that incorporate different heights and widths would be of interest.

Conclusions

For most experienced weightlifters, using alternate plate sizes in an attempt to exploit the common size and weight expectation, will likely not improve performance in the bench press exercise beyond what would be experienced with a typical weight plate arrangement. However, alternate arrangements do not seem to reduce performance and may even be marginally beneficial for those whom the bench press load is near the lifter's 1RM.

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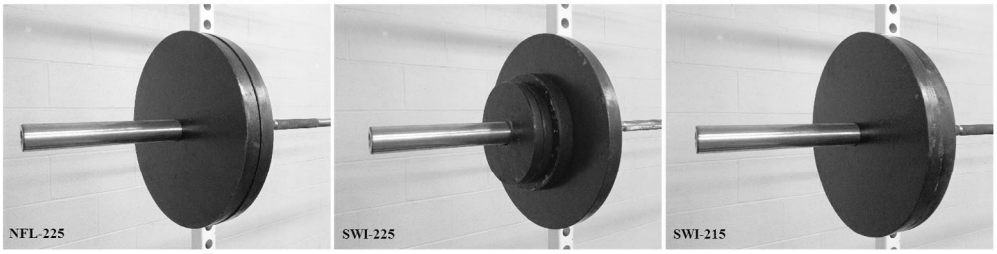


Bench Press Repetitions-to-Fatigue Barbell Configurations

396x102mm (300 x 300 DPI)

Table 1: Data collection timeline

	Week 1 Familiarization	Week 2 Test 1	Week 3 Test 2	Week 4 Test 3	Week 5
Stations 1, 4, 7	NFL-225	NFL-225	SWI-225	SWI-215	1RM
Stations 2, 5, 8	NFL-225	SWI-215	NFL-225	SWI-225	1RM
Stations 3, 6, 9	NFL-225	SWI-225	SWI-215	NFL-225	1RM

Table 2: Counterbalance of Testing Order and Repetitions-to-Fatigue tests and Barbell Configurations

	Repetitions-to-Fatigue Data Collection Sessions		
Testing Order Group	Week 2	Week 3	Week 4
A (n=23)	NFL-225	SWI-225	SWI-215
B (n=25)	SWI-215	NFL-225	SWI-225
C (n=24)	SWI-225	SWI-215	NFL-225

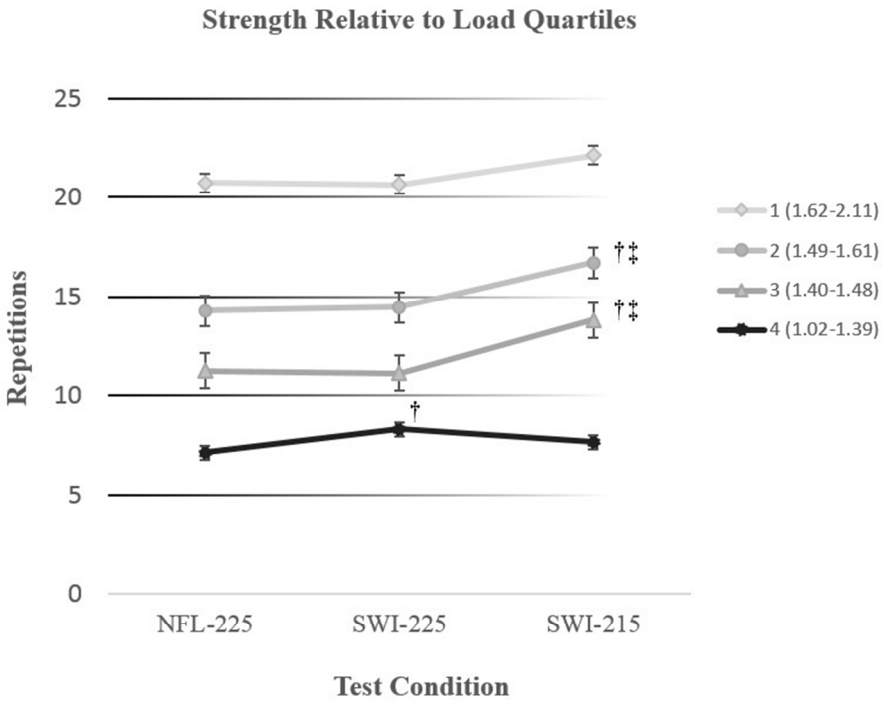
Test	Barbell Configurations
NFL-225	Two 45 lb plates on each side of 45 lb Olympic Barbell (225 lb total)
SWI-225	One 45, 25, 10, and 10 lb plate on each side of a 45 lb Olympic Barbell (225 lb total)
SWI-215	One 45 and 40 lb plate on each side of a 45 lb Olympic Barbell (215 lb total)

Table 3. Quartile performance variables for the three repetition-to-failure bench press tests and 1RM bench press. All values Mean ± SD

	Repetitions			
	NFL-225	SWI-225	SWI-215	1RM (kg)
Quartile 1 (n=21)	20.7 ± 4.2	20.7 ± 4.6	22.1 ± 4.9	180.0 ± 15.2
Quartile 2 (n=17)	14.3 ± 4.0	14.8 ± 3.5	16.7 ± 4.7†‡	157.3 ± 3.8
Quartile 3 (n=17)	11.2 ± 3.0	11.1 ± 3.4	13.8 ± 2.9†‡	144.9 ± 2.9
Quartile 4 (n=17)	7.1 ± 2.7	8.3 ± 3.0†	7.6 ± 2.9	126.8 ± 10.4
Team (n=72)	13.7 ± 6.2	14.0 ± 6.0	15.4 ± 6.6	153.8 ± 22.3

†Different from NFL-225 ($p<0.05$), ‡Different from SWI-225 ($p<0.05$)

Figure 2: Test Condition x Quartile plot



†Different from NFL-225 ($p<0.05$)

‡Different from SWI-225 ($p<0.05$)

Quartiles based on strength relative to test load (1RM/225)

Table 4: Testing Order and Quartiles

Testing Order Group	Testing Order Week 2 - Week 3 - Week 4	Q1 n=21	Q2 n=17	Q3 n=17	Q4 n=17
A	NFL-225 - SWI-225 - SWI-215	8	5	8	2
B	SWI-215 - NFL-225 - SWI-225	6	3	3	13
C	SWI-225 - SWI-215 - NFL-225	7	9	6	2