APPLICATION OF THE PREDICTED REPETITIONS-TO-FAILURE PERCEIVED EXERTION SCALE FOR THE NFL-225 BENCH PRESS TEST

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ABSTRACT

APPLICATION OF THE PREDICTED REPETITIONS-TO-FAILURE PERCEIVED EXERTION SCALE FOR THE NFL-225 BENCH PRESS TEST

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PURPOSE: To assess how accurately Division II NCAA football players can predict repetitions-to-failure (RTF) during the bench press exercise using an absolute load of 225-lbs by comparing predicted repetitions-to-failure with actual repetitions-to-failure. METHODS: Twenty football players (age 20 ± 2 years; height 1.85 ± .06 m; weight 110.1 ± 19.3 kg) without muscular or skeletal injuries were tested for their 1repetition maximum (1-RM) in the bench press, and then performed 1 set to concentric failure with 225-lbs. Subjects predicted how many repetitions they could perform after the warm-up and again after the fourth, eighth, twelfth repetitions. A general regression analysis was used to determine the relationship between predicted repetitions-to-failure and actual repetitions-to-failure after the warm-up and after the 4^{th}, 8^{th}, and 12^{th} repetitions. Additionally, the relationship between predicted- and actual-repetitions-to-failure and 1-RM after the warm-up and after the 4^{th}, 8^{th}, and 12^{th} repetitions was determined using a general regression analysis. RESULTS: The general regression equation indicated significant positive relationships between predicted- and actual repetitions-to-failure after the warm-up & after the 8^{th} and 12^{th} repetitions ($p < .05$). A significant relationship was not found between predicted- and-actual-repetitions-to-failure after the 4^{th} repetition ($p < .05$).

Significant positive relationships were found between actual and predicted repetitions-to-failure after the warm-up and 1-RM and after the 4th repetitions ($p < .05$); however significant relationships between actual- and predicted repetitions-to-failure were not found after the 8th & 12th repetitions ($p < .05$). DISCUSSION: Subjects were more accurate in predicting repetitions-to-failure in the latter half of the set. This may be due to fatigue influencing their physiological and physical protective mechanisms or a learned effect from experience in weightlifting. CONCLUSION: It may be possible for Division II NCAA football players to regulate volume during the 225-lb bench press test; however it is not supported by the current investigation to use the RTF scores to predict 1-RM.

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INTRODUCTION

Most NFL Strength and Conditioning Coaches implement some type of resistance training program for their NFL team and many coaches are in agreement that resistance training plays an important role in their athlete's careers (Ebben & Blackard, 2001). Resistance training has been shown to improve skill related fitness components such as; speed, agility, power, balance, and coordination (Kraemer, Ratamess & French, 2002). These skills set the base for motor performance seen in the sport of football (Kraemer et al., 2002). One of the most important resistance training exercises used by NFL strength and conditioning coaches is the bench press (Ebben & Blackard, 2001). Over half of the NFL strength and conditioning coaches surveyed in a study done by Ebben and Blackard (2001) ranked bench press as one of the five most important resistance exercises for competition in the NFL.

The NFL 225-lbs bench press test is included in the battery of tests during the NFL combine every year (McGee & Burket, 2003). This is a test of muscular endurance where each participant performs one set of bench press to volitional failure using an absolute load of 225-lbs. This is the only test used to measure upper-body muscular strength in the entire combine (McGee & Burket, 2003). The NFL 225-lbs bench press test has also been used to predict 1RM values in college football players as a way to limit the risk of injury while testing muscular performance (Mayhew, Ware, Bemben, Ward, Farris, Juraszek, & Slovak, 1999).

A rating of perceived exertion (RPE) scale is a numerical representation of an individual's perceptual response to training and is a viable method of measuring exertion during training (Borg 1982). The first RPE scale developed was a 15-point scale created and implemented by Gunnar Borg and used to assess aerobic exercise performance (Borg 1982). The scale ranged from 6-20 where a rating of 6 registered as no effort, and a rating of 20 was failure. Not soon after, a 10-point category (C) ratio (R) (BORG CR10 Scale) scale was created. This scale ranged from 0-10 where a rating of 0 registered as no effort and a rating of 10 was nearly maximal effort (Borg 1982). Following the creation of the Borg CR10 scale, the visually aided OMNI-resistance exercise scale (OMNI-RES) was created (Borg 1982). The OMNI scale uses mode specific pictures, numerical ratings as well as verbal descriptions for the increasing intensity gradient (Gearhart et al., 2009).

More recently, versions of previously used RPE scales have been developed and are being used specifically for measuring repetitions-in-reserve (RIR), or repetitions-to-failure (RTF) in resistance exercise. These two terms (RIR, RTF) use different terminology but are measuring the same variable: how many repetitions an individual can complete before volitional failure (Hackett, Johnson, Halaki & Chow, 2012; Hackett, Cobley, Davies, Michael & Halaki, 2016; Zourdos et al., 2016). It is argued that using this type of RPE scale may improve the ways relative strain is expressed during resistance exercise (Hackett et al., 2012, Zourdos et al., 2016). It has also been argued that using an RTF scale of perceived exertion may allow for a more accurate prescription of intensity when loads are close to maximal. Compounding external factors such as: phase of season, amount/quality of sleep, eating and drinking habits, personal issues, and

so on may affect training performance on a day-today basis. Implementing an RTF/RIR based resistance program may aid in avoiding the effects of overtraining exacerbated by the previously mentioned factors (Helms et al., 2016).

Taking these factors into consideration a deeper look at perceived effort in the form of repetitions-to-failure is needed.

LITERATURE REVIEW

Methods

Google scholar and Humboldt State University's online library were used to search key databases for the research used in this review of literature. Search terms: "rate of perceived exertion and resistance exercise", "repetitions-to-failure and resistance exercise", "repetitions-in-reserve and resistance exercise" were used to find relevant research for this review. Out of the thirty-five articles found, eight relevant studies were chosen and summarized for the purposes of this review of literature.

Table 1. Summary of Literature Review Studies

Study	Mode	Subjects	Scale Used	Methods	Results
Ebben and Blackard, (2001)	Survey	26 out of 30 NFL Strength and Conditioning Coaches		Survey asking background infomation, physical testing used (strength, speed, agility, flexibility).	Ranked 5 most important exercises: squat, bench press, power cleans
Robertson et al., (2003)	Biceps curl, Knee extension	(n=40) 20 male, 20 female, clinically normal subjects	OMNI-RES	1RM, 65% for knee extension & biceps curl during experimental trials (3 set of 4-8 & 3 sets of 8-12)	Females and males = positive linear regression between RPE of active muscle and RPE in the overall body. Results are in general agreement with previous research using OMNI-RES scale.
Egan et al. (2006)	Squat	14 college aged women (22yrs SD =3)	Borg CR-10 scale, Session RPE	1 RM, Traditional = 6x6 80%, Super Slow = 6x6 55%, Explosive = 6x6 30%	No significant difference was seen between average RPE and session RPE. Power = significantly lower average and

Study	Mode	Subjects	Scale Used	Methods	Results
					session RPE compared to both super slow training and traditional training
Gearhart et al. (2009)	Leg Press, Lat Pull, Chest Press, Leg extension, Leg curl, Arm extension, Arm curl	22 Men, 27 Women aged 60-69 years old	OMNI-RES	1RM, RPE Collection. 12 week training protocol (3 times/week) 75% 1RM 8-12 reps	The results agree with the effort continua model. The 12-week model results in increased muscular strength and an increase in absolute load lifted at 3 criterion OMNI-RES RPE (4, 6, 8).
Tiggerman et al. (2010)	Bench press, Leg press	30 apparently healthy men (age=18-34 years) 3 groups (10 active, 10 sedentary, 10 experimental)	Borg Perceived Exertion scale (6-20)	1RM	Greater RPE=greater load
Hackett et al. (2012)	bench press, squat	17 male bodybuilders		5x10 @ 70%, asked RPE/RIR after 10th rep-continued until failure	1. Estimated & actual RTF decreased across sets for bench & squat. 2. Actual RTF

Study	Mode	Subjects	Scale Used	Methods	Results
					= greater than estimates for bench & squat
Hakett et al. (2016)	Chest Press, Leg Press	53 men, 28 women (n=81)	Estimated Repetitions to Failure (ERF)	1RM, multiple sets of 10, or failure (70&80%) 5 sets per exercise	Accuracy for ERF differed over ARF range, with greater accuracy with lower ARF's. Chest press=greater accuracy. Men = greater accuracy
Servais et al. (2015)	Bench Press	Resistance trained males and females (at least two years of previous weight training experience)	Modified 0-10	1RM, Muscular endurance protocol (4xfailure @ 65% w/30 sec rest. RPE (modified 0-10 scale), predicted how many repetitions before set	no significant correlation between RTF for females; negative correlation for men. Negative correlation for both men and women between actual reps to failure and RPE. No differences between predicted and actual RTF.

Study	Mode	Subjects	Scale Used	Methods	Results
Zourdos et al. (2016)	Squat	23 males, 6 females (college age) Split into 2 groups: Experienced Squatters (ES n = 15) & Novice Squatters (NS n =14)	Repetitions in Reserve (RIR 1-10)	1RM (USAPL), 1 Rep at 60%,75%,90%, set of 8 70%	Strong inverse relationship between average velocity at all intensities and RPE in both ES and NS

Notes: RPE: **Rate of Perceived Exertion,** 1RM: **1 Repetition Maximum,** CR-10: **Category-Ratio 10 Point Scale,** RIR: **Repetitions in Reserve,** USAPL: **USA Powerlifting,** RTF: **Repetitions-to-failure,** ERF: **Estimated Repetitions-to-failure**

Gender

In a study done by Robertson et al. (2003) 65% 1RM was used in the biceps curl and knee extension exercises while RPE scores were taken for active muscle and overall body in the middle of each set (1 set of 4 repetitions, 1 set of 8 repetitions and 1 set of 12 repetitions), and on the final repetition of each set for both exercises for men and women. Results showed that RPE values in the middle of set and on the final repetition were greater for both men and women during the knee extension exercise compared to the biceps curl exercise. Findings were similar in men and women for the RPE values of the active muscle and overall body (Robertson et al., 2003).

The results of the previously mentioned study are in relative agreement with a study done by Servais et al. (2015) who found that there were no differences in predicted and actual repetitions-to-failure (RTF) in resistance trained men and women. In the investigation conducted by Servais et al. (2015), participants completed four sets to failure with 65% of their 1RM in the bench press exercise. Prior to beginning each set, subjects were asked to estimate RTF. Results showed no significant difference between predicted and actual RTF in trained men and women (Servais et al., 2015). Additionally, all subjects' accuracy in predicting repetitions-to-failure increased, as fatigue became a factor.

Hackett et al. (2016) also investigated the differences in RTF values between men and women using 70% 1RM and 80% 1RM in the chest press and leg press exercises. Subjects performed 5 sets of 10 repetitions for each exercise at both intensities. At the completion of the 10^{th} repetition of each set, subjects reported their estimated-repetitions-

to-failure (ERF), before proceeding to actual failure and recording their actual-repetitions-to-failure (ARF). Results showed that greater accuracy of ERF was found for the chest press compared to the leg press exercise, and that there were only differences in accuracy of ERF between genders in the leg press exercise where four or more repetitions were completed. It is hypothesized that these results were linked to a difference in sensory organ density between upper and lower extremities in men and women.

Level of Experience

Resistance training experience levels and RPE have also been analyzed. Servais et al. (2010) used the bench press and leg press exercises in three different populations: sedentary, physically active, and resistance trained individuals. This investigation aimed to match loads (%1RM) to four ratings on the Borg 15-point scale and analyze the behavior of physical exertion at those corresponding intensities. It was found that Resistance-exercise-trained individuals, physically active individuals, and sedentary individuals all interpret RPE similarly: as intensity (%1RM) increases, RPE also increases. Additionally, as intensity (%1RM) increases, the variability of RPE scores decreased (TIggemn et al., 2010; Hackett et al., 2016).

Gearhart et al. (2009) used a population between the ages of 60-69 years old with experience levels ranging from sedentary to physically active. Participants were required to use the OMNI-RES RPE scale to quantify the intensity (%1RM) of their exercises during a twelve-week training program. Their 1RM values were measured in seven different machine assisted resistance exercises before beginning the program. 75% of

their 1RM was used at the onset of the program for every exercise; however, participants could increase resistance to an 8 on the OMNI-RES RPE scale if strength gains were observed. Results showed that every individual's strength increased as evidence by increased 1RM as well as resistance associated with certain RPE values (i.e., 4, 6, and 8).

Hackett et al. (2012) conducted a study on bodybuilders (resistance trained 5-6x per week) where each subject was tested in the bench press and squat exercises using 70% of their 1RM. Subjects were required to do 5 sets of 10 repetitions in each exercise. After the completion of the 10^{th} repetition of each set, subjects were asked to give an RPE rating as well as their predicted repetitions-to-failure (RTF). Results showed that the predicted RTF scale was accurate for sets 3, 4, and 5; however less accurate during sets 1, and 2 for the bench press, and set 1 in the squat. This suggests that as trained individuals become more fatigued, their accuracy of predicting exercise end point may become more accurate (Hackett et al., 2012).

Zourdos et al. (2016) conducted a study analyzing the differences in Repetitions-in-Reserve scores between experienced and novice squatters. RPE ratings in the form of Repetitions-in-Reserve (RIR) scores (where an RPE of 10 is equal to and RIR of 0, and an RPE of 9 is equal to an RIR of 1 and so on) were gathered when comparing scores between experienced and novice squatters (Zourdos et al., 2016). Subjects completed 1 set of 1 repetition at 60%, 75%, and 90% of previously gathered 1RM followed by 1 set of 8 repetitions at 70% of 1RM. After each set, subjects were asked to report their RPE values in the form of RIR scores. Results showed that experienced squatters reported lower RIR scores (Higher RPE scores) at higher intensities and at 1RM than novice

squatters suggesting that novice squatters may not be able to achieve a true 1RM from their inability to recruit high-threshold motor units (Zourdos et al.,2016)

Style of Training and Intensity

The way an individual trains may also affect the way they perceive exertion. Egan, Winchester, Foster and McGuigan (2006) compared RPE scores across three different "styles" of training for the squat exercise. These "styles" are defined as: Power Training (30%1RM) – move the weight as fast as possible, Super-slow Training (55%1RM) – move the weight much slower than normal, and Normal Training (80%1RM) – move the weight as you normally would during training. Results showed that power training with a light load produced a much lower Session and average RPE than that of "super slow" and "normal" training. These findings are consistent with current research that greater intensities elicit greater RPE responses (Tiggeman et al., 2010; Hackett et al., 2012; Hackett et al., 2016).

Each study that investigated RPE used a load relative to subjects' 1RM when designing the experimental. Robertson et al. (2003) used 65% 1RM when assessing RPE in the biceps and knee curl exercises. Egan et al. (2006) used 30%, 55% and 80% 1RM when analyzing RPE responses in different "styles" of resistance training. Gearhart et al. (2009) used 75% 1RM when testing the effectiveness of RPE in relation to strength gains in older adults. And Tiggeman et al. (2010) aimed to correspond RPE ratings to certain percentages of 1RM.

Similar to research involving RPE, research investigating RTF and RIR use loads relative to subjects' 1RM when designing their protocol. When determining the validity of a RTF scale for predicting muscular failure (Hackett et al., 2012) used 70% of subjects' 1RM. When investigating if men and women could accurately predict RTF in the bench press exercise (Servais et al., 2015) used 65% of subjects' 1RM. Hackett et al. (2016) examined the differences in RTF values between men and women using 70% and 80% of subjects' RTF. Finally, Zourdos et al. (2016) used 60%, 70%, 75%, and 90% when comparing RPE ratings based on RIR.

Summary

It has been shown that men and women do not necessarily perceive exertion differently (Robertson et al., 2003; Servais et al., 2015., Hackett et al., 2016). However, type of exercise, amount of muscle involved, and %1RM may have an effect on perceived exertion. Using isotonic isolation exercises compared to compound multi-joint exercises elicit different RPE responses (Robertson et al., 2003).

Resistance-training experience has also been found to play a role in how subjects perceived resistance training effort. Experienced lifters reported significantly higher average RPE (Lower RTF/RIR) scores than novice lifters when measuring 1RM values (Zourdos et al., 2016). However, while experienced lifters experience higher RPE's at loads close to 1RM, novice lifters and experienced lifters experience average RPE similarly (Tiggeman et al., 2010; Gearhart et al., 2009; Hackett et al., 2012; Zourdos et al., 2016).

Both RTF/RIR and RPE are valid methods for assessing resistance exercise intensity (Robertson et al., 2003; Egan et al., 2006; Gearhart et al., 2009; Tiggeman et al., 2010; Hackett et al., 2012; Servais et al., 2015; Hackett et al., 2016; Zourdos et al., 2016). Although they are both subjective measurements, they are consistent across gender and age (Robertson et al., 2003; Gearhart et al., 2009; Hackett et al., 2016). Researchers have been able to establish a relationship between intensity and RPE & RTF/RIR measurements: the higher the intensity (%RM), the more accurate the RPE and RTF/RIR measurements will be (Egan et al., 2006; Tiggeman et al., 2010; Hackett et al., 2016). Researchers have controlled intensities by prescribing previously determined loads i.e., 65, 75, 80%, etc. and making the load relative to each subject's strength (Roberston et al., 2003; Egan et al., 2006; Gearhart et al., 2009; Tiggeman et al., 2010; Hackett et al., 2012; Servais et al., 2015; Hackett et al., 2016; Zourdos et al., 2016).

Problem Statement

It has yet to be seen how using an absolute intensity will affect predicting repetitions-to-failure. Additionally, it has yet to be seen how accurately NCAA Division II athletes can predict repetitions-to-failure in the bench press exercise. There is insufficient research involving and implementing a Repetitions-to-Failure (RTF) based RPE scale to identify resistance training intensity in the bench press exercise (Helms et al., 2016). Additionally, many studies using these scales focus on the difference between sex (Robertson et al., 2003; Gearhart et al., 2009; Hackett at al., 2016;) and training status of participants (Tiggerman et al., 2010; Zourdos et al., 2016). There has been no research conducted

using a RTF based RPE scale on an athletic population, more specifically division II football players. Furthermore, every study conducted utilizing any type of RPE scale uses a %1RM relative to each subject. Using an absolute load of 225-lbs for the bench press exercise in conjunction with an RTF based RPE scale may be useful for resistance exercise prescription in NCAA Division II athletes.

Purpose

The purpose of this study was to assess how accurately division II NCAA football players could predict repetitions-to-failure during the bench press exercise using an absolute load of 225-lbs by comparing predicted repetitions-to-failure with actual repetitions-to-failure.

Hypothesis

Due to the role fatigue plays in predicting repetitions-to-failure, the investigator hypothesized that as fatigue began to take effect, Division II college football players would predict repetitions-to-failure more accurately. Since subjects had multiple years of resistance training experience, they would have a developed template RTF scale to compare their current performance to.

Rationale

Previous research suggests that as subjects become more fatigued, the more accurate their estimations become for predicting exercise end point (Hackett et al., 2012, Servais et al.

(2015). In both of these studies, subjects performed 4 sets of bench press to failure. The findings in both studies showed that subjects' predicted repetitions-to-failure became more accurate in the 3rd, and 4th sets. Based off the results of these investigations, it was assumed that as subjects in this investigation reach repetitions 8, 12, or 16 and begin to feel fatigue, their accuracy in predicting repetitions-to-failure would become more

METHODS

Experimental Approach to the Problem

There were a total of two lab visits for each subject, one familiarization session and one experimental session. During the familiarization session, each subject performed a 1-RM in the bench press exercise. The experimental session was scheduled a minimum of 48 hours after the familiarization session. The experimental session consisted of a post-activation-potentiation warm-up to prepare subjects for a maximum-repetitions set of bench press with an absolute load of 225-lbs. Prior to the first repetition and following the fourth, eighth, twelfth, sixteenth, and twentieth repetitions (if possible), subjects were asked to predict how many repetitions they could complete before concentric failure, and then performed as many repetitions as possible.

Subjects

Twenty Division II NCAA college football players participated in this study after obtaining approval from the Institutional Review Board at Humboldt State University. Subjects were cleared to participate in this study if they were cleared for athletic participation (Servais et al., 2015). Subjects also completed a health history questionnaire as well as the PARQ before participating in the study. Subjects were excluded from participation if they were not cleared for athletic participation. Bodyweight measurements were taken. Subjects were instructed to avoid the consumption of food 2

hours prior to testing, the consumption of alcohol 24 hours prior to testing, and the consumption of caffeine 3 hours prior to testing.

Procedures

One Repetition Maximum and Familiarization Session

Subjects were instructed how to properly perform the bench press exercise through a full range of motion. It was important that each subject properly complete both the eccentric and concentric portion of the bench press. The eccentric portion of each repetition was not complete until the bar touched the subject's chest; the concentric portion was not complete until the subject's elbows were completely extended. Warm-up sets consisting of 10 repetitions at 50%, 5 repetitions at 70%, 3 repetitions at 80%, and 1 repetition at 90% of self-reported 1-RM were completed with a 3-minute rest period following each set (Kwon, 2009). Following the warm-up, subjects performed single repetitions followed by a 5-minute rest period. This process was repeated until the subject could no longer increase the load, or they could no longer complete the movement with proper technique. The final repetition completed through a full range of motion was recorded as the subject's 1-RM. Calculations were performed following the completion of the 1-RM testing to determine what percentage of each subject's 1-RM 225-lbs would equate to.

Experimental Session.

The second visit was scheduled 48-72 hours later. During the second visit, subjects were asked if any soreness was still present or if any injuries occurred as a result of the 1RM testing. In the presence of soreness, testing was pushed back an additional day. Subjects

performed a separate warm-up consisting of: 1 set of 10 repetitions at 50% of previously gathered 1RM followed by a 3 minute rest period; 2 sets of 4 repetitions at 70% of previously gathered 1RM followed by a 3 minute rest period; and 1 set of 1 repetition with 225-lbs followed by a 5 minute rest period. If 70% of the subjects 1RM was greater than 225-lbs, the subject would still complete 1 repetition at 225-lbs before beginning the experimental protocol. Following the five minute rest period, subjects performed the experimental protocol, which consisted of 1 set to concentric failure with 225-lbs. Before the subject began the set, they were asked to predict how many repetitions they would be able to perform before failure. They were asked again after the fourth, eighth, twelfth, and sixteenth repetitions if possible.

Statistical Analysis

Before using parametric tests, the data was first analyzed using a box plot graph to determine if there were any outliers, and the distribution of each variable was examined with the Kolomogorov-Smirnov normality test. Homogeneity of variance was verified with a Levene's test.

Data gathered from this investigation was analyzed using STATISTICA version 7.1 software (StatSoft, Inc., Tulsa, OK).

The relationship between estimated- and actual-repetitions-to-failure after each benchmark repetition (4^{th} repetition, 8^{th} repetition, 12^{th} repetition, 16^{th} repetition, etc.) was assessed using a general regression equation for the 225-lbs bench press test.

RESULTS

Summary of the participant's descriptive statistics are listed in Table 2. The mean 1-RM bench press was 139.88 ± 13.88 kg. The mean percentage of 1-RM that 225-lbs represented was 74 ± 11%. The summary of the participant's predicted- and actual-repetitions-to-failure are listed in Table 3. The mean repetitions-to-failure was 12.39 ± 2.37 repetitions.

Regression analysis yielded a significant positive correlation between predicted-repetitions-to-failure and actual-repetitions-to-failure after the warm-up in the 225-lb bench press test ($r2$ = 0.22, p = 0.048) (Figure 1) as well as after the 8th repetition ($r2$ = 0.45, p = 0.002) (Figure 3). However, there was no significant correlation between predicted-repetitions-to-failure and actual-repetitions-to-failure after the 4th repetition ($r2$ = 0.15, p = 0.12) (Figure 2).

Almost half (N=8) of the participants experienced concentric failure before reaching the twelfth repetition. The remaining subject's (N = 10) results were used to analyze the relationship between predicted- and actual-repetitions-to-failure after the 12th repetition. The regression analysis showed a significant, strong correlation between predicted and actual repetitions-to-failure after the 12th repetition ($r2$= 0.76, p = 0.001) (Figure 1).

A significant, positive correlation occurred between the number of actual-repetitions-to-failure in the NFL 225-lb bench press test and 1-RM ($r2$ = 0.72, p = 0.001)

(Figure 2), while a significant, but much smaller positive correlation occurred between the number of predicted-repetitions-to-failure after the warm-up and 1-RM ($r2$ = 0.22, p = 0.48) (Figure 2). A similar correlation occurred between predicted-repetitions-to-failure after the 4th repetition and 1-RM ($r2$= 0.27, p = .028), while the correlation between predicted-repetitions-to-failure after the 8th & 12th repetitions and 1-RM was not significant ($r2$ = 0.116, p = .067).

Table 2. Descriptive Statistics of subjects

Variable		Range
Age	20.39 ± 1.75	18-24
Height (cm)	185.44 ± 6.34	68-75
Weight (kgs)	110.06 ± 19.25	86-120
1RM (kgs)	139.88 ± 13.88	116-166
%1-RM	74 ± 11	88 - 62
Strength/Weight	1.30 ± 0.22	0.88-1.78
Experience (yrs)	4.78	4-7

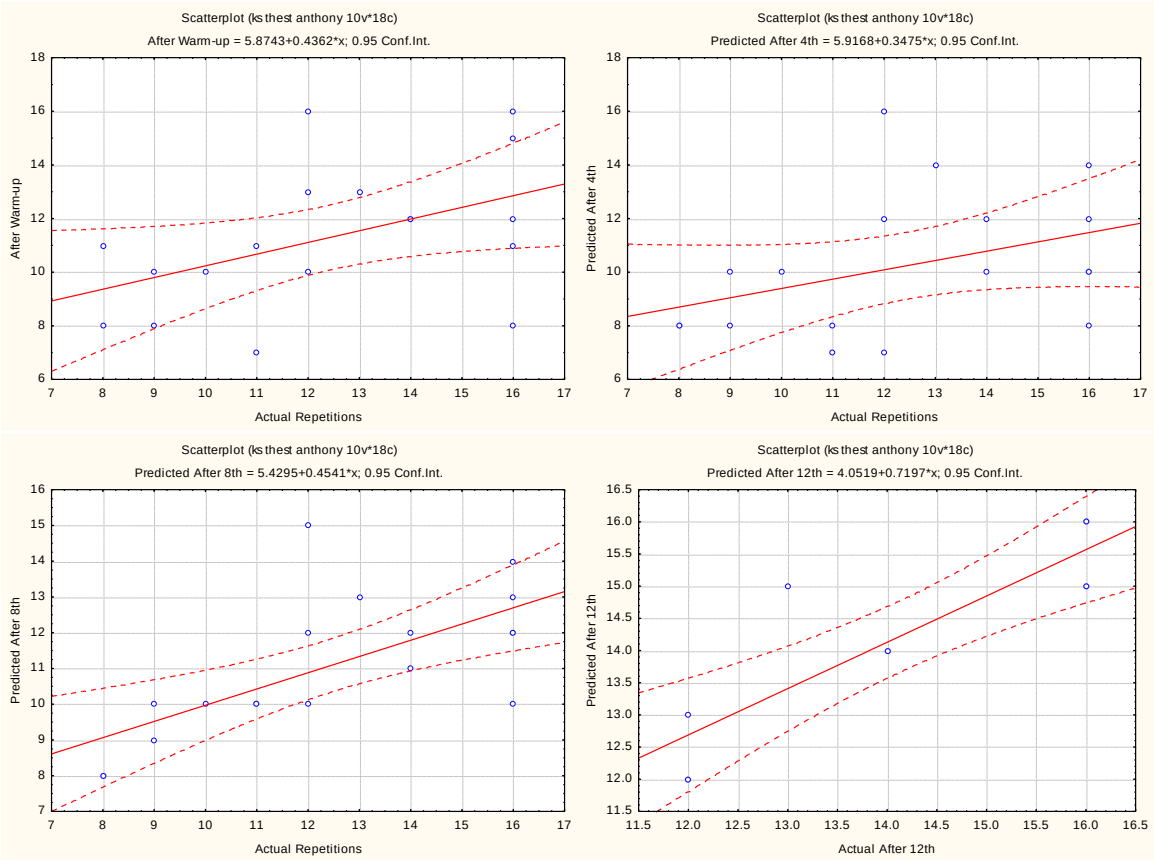
+1RM = 1 Repetition Maximum. Data are presented as mean ± SD.
+ %1-RM = Percentage of 1RM that 225-lbs represents

Table 3. Descriptive Statistics of Predicted and Actual Repetitions-to-Failure

Repetition	Predicted	Actual	r^2	p
After warm-up (N=18)*	11.28 ± 2.67	12.39 ± 2.89	0.22	0.048
After 4th (N=18)	6.22 ± 2.62	8.55 ± 2.57	0.12	0.117
After 8th (N=18)*	3.06 ± 1.95	4.44 ± 2.89	0.45	0.022
After 12th (N=10)*	2.20 ± 1.48	2.1 ± 1.52	0.76	0.001

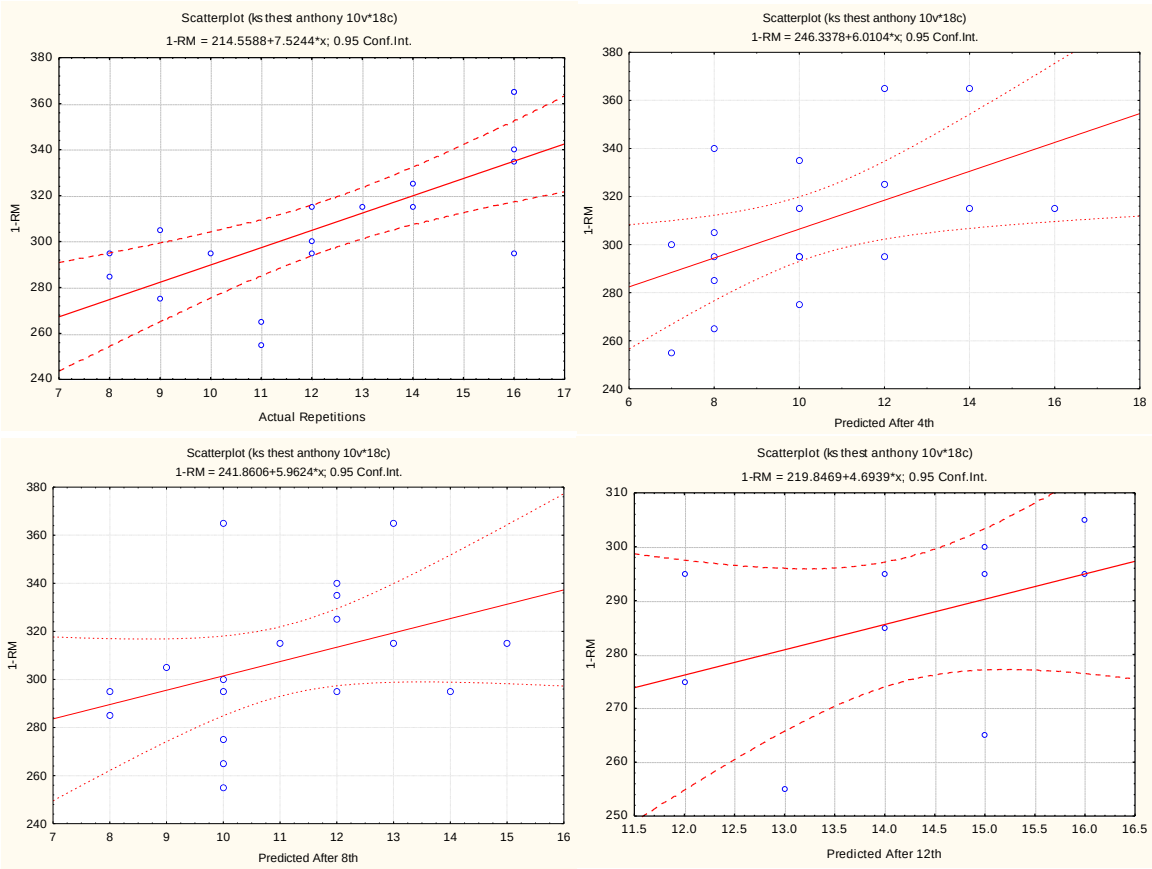
*Relationship between predicted- and actual-repetitions-to-failure were significantly correlated.
+ r^2 = Strength of relationship between predicted and actual repetitions to failure
+ p = level of significance of relationship between predicted and actual repetitions to failure

Figure 1. Correlation between predicted and actual repetitions-to-failure



*Correlation between actual repetitions completed during the NFL 225-lb bench press test and predicted repetitions-to-failure after: the warm-up, 4th repetition, 8th repetition & 12th repetition. Solid and dashed lines represent fitted linear model, with 95% confidence intervals.

Figure 2. Correlation between repetitions completed and 1-RM



*Correlation between actual and predicted repetitions after the 4th, 8th & 12th repetitions in the NFL 225-lb bench press test and 1-RM. Solid and dashed lines represent fitted linear model, with 95% confidence intervals.

DISCUSSION

The purpose of this study was to assess how accurately Division II NCAA football players could predict repetitions-to-failure during the NFL 225-lb bench press test. Both predicted-repetitions-to-failure and actual-repetition-to-failure were recorded after 4 - predetermined repetitions during 1 set to failure during the NFL 225-lb bench press test. The results showed positive correlations between predicted- and –actual repetitions to failure after the warm-up and after the 8^{th} & 12^{th} repetitions. The correlation between predicted-and actual-repetitions-to-failure grew stronger as participants completed more repetitions and fatigue became a factor, supporting our hypothesis. The increase in correlation between predicted- and actual-repetitions to failure after the 8^{th} and 12^{th} repetitions suggests that as Division II NCAA football players completed more repetitions and acutely experienced fatigue, they became more accurate in predicting of repetitions-to-failure during the NFL 225-lb bench press test. However, the correlation between predicted- and actual-repetitions-to-failure was not significant after the 4^{th} repetition insinuating that after completing 4 repetitions, Division II NCAA football players' predictions were less accurate due to an unidentified psychological or physical factor.

The results of this study are similar and consistent with previous research assessing accuracy in estimation of repetitions-to-failure. Hackett et al. (2012), Servais et al. (2015) & Hackett et al. (2016) all found that accuracy in estimation of repetitions-to-failure was much lower in earlier sets. While the current investigation used one set to

concentric failure with a load of 225-lbs in the bench press, Hackett et al. (2016) & Servais et al. (2015) both used four sets to concentric failure in the bench press and found that subjects were much more accurate in predicting repetitions-to-failure in the final two sets than in the first two. Hackett et al. (2016) attributed this inaccuracy to the level of fatigue in the earlier sets being much lower compared to the level of fatigue in later sets. Servais et al. (2015) suggested that in addition to fatigue, subjects might have been more accurate in the later sets due to central processing of physiological disturbances from the previous sets. Noakes, Gibson and Lambert's (2005) central governor theory could explain this possible increase in accuracy of estimating repetitions to failure. This theory argues that exercise termination is never actually determined by the failure of homeostasis. It is instead caused by internal afferent signals warning the body to terminate exercise before something catastrophic happens leading to the failure of homeostasis (Noakes, Gibson & Lamberts, 2005). Considering the subjects were Division II NCAA football players, it is likely that they had performed a set to concentric failure with 225-lbs in the past which contributed to the creation of a "template" of the sensation leading to failure. Developing this "template" could be valuable for athletes in the prescription of resistance exercise using a repetitions-to-failure scale by enhancing athletes' abilities to choose loads that correspond with target RTF ranges (Helms, 2016).

Overall, a significant positive correlation was also seen between actual-repetitions-to-failure and 1-RM. Which intuitively suggests that the stronger a subject was, the more repetitions they could perform with 225-lbs. A significant, but weaker positive correlation was also seen between predicted-repetitions-to-failure and 1-RM.

Additionally, no significance was found between predicted repetitions-to-failure and 1-RM after the 8th and 12th repetitions. These results are in disagreement with previous research that concluded that using the repetitions-to-failure in the NFL 225-lb bench press test could be used to predict 1RM with reasonable accuracy in college football players (Mayhew et al., 1999; Mayhew et al., 2002; Chapman, Whitehead & Binkert, 1998). However, it was also shown that accuracy in predicting 1-RM decreased if subjects completed >10 repetitions (Mayhew et al., 1999; Mayhew et al., 2002; Chapman et al.., 1998; Baechel & Earle, 2008). NSCA guidelines suggest that the most accurate relationship between percentage of 1-RM and maximum repetitions possible is for loads ≥75% 1-RM (Baechel & Earle, 2008). Furthermore, it is stated that as percentage of 1-RM decreases, variability of number of repetitions that can be completed increases (Baechel & Earle, 2008). Considering fourteen of the eighteen subjects in the current investigation were able to complete >10 repetitions and the mean percentage of 1-RM that 225-lbs represented was < 75% 1-RM, the NFL 225-lb bench press test may be inappropriate to use for predicting 1-RM for these athletes (Chapman et al., 1998; Baechel & Earle, 2008)

Limitations to the level of control included subject-dependent factors. Sleep and nutritional habits may have affected the results from the 1-RM and/or Experimental session. Inadequate sleep and/or nutritional status at the time of testing may have resulted in inaccurate 1-RM and 225-lb bench press test values. If a subject's sleep and nutrition needs were adequate during 1-RM testing, 1-RM values may be accurate. However, if a subjects sleep and nutrition needs were inaccurate during 1-RM testing, 1-RM values

may be underestimated. The same could be said for the experimental session; if sleep and nutrition needs were adequate or inadequate, subjects completed repetitions could have been affected positively or negatively. Although subjects were instructed to get adequate sleep and meet nutritional needs throughout the course of the study, it was up to each subject to decide how strictly they followed instructions.

Delimitations of the current investigation included the announcement of the cancellation of football at Humboldt State Football, the use of only the bench press, the constant load of 225-lbs and the use of only football players. The cancellation of football at Humboldt State Football was released at the beginning of this study. Because of this announcement, the quality and quantity (sample size) of football players able to participate were lower than previous years due to the increase in transfers following the announcement. The bench press exercise was the only exercise used because of its popularity, availability, ease for spotting, and relatively low risk of injury. 225-lbs was used because of the relevance to the NFL combine. Finally, only Division II NCAA football players were included in this investigation.

PRACTICAL APPLICATION

Upper body muscular strength is an important part of any football strength program. The NFL 225-lb bench press test is a popular method for training upper body muscular strength and endurance. However, using this test to train to failure consistently can lead to overtraining and injury. Using a repetitions-to-failure scale of perceived exertion can allow athletes to self-select repetition ranges and/or appropriate loads on a set-to-set basis and could more accurately gauge intensity and/or repetitions-to-failure at near maximal loads. This may help strength and conditioning coaches accurately optimize training programs for their athletes by utilizing the protocol appropriate for each sport or athlete.

Future Research

Future research should study trained individuals and their accuracy at self-selecting load in relation to assigned repetition ranges. This could allow to further the understanding of the perceptual response to fatigue while allowing for the self-selection of intensity.

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APPENDICES

A. Humboldt State University Human Performance Lab Health History Questionnaire

B. Informed Consent Form

Appendix A.

HUMBOLDT STATE UNIVERSITY HUMAN PERFORMANCE LAB HEALTH HISTORY QUESTIONNAIRE

Health History and Training Status Questionnaire

Name _____

Address _____

Home Phone _____ Work Phone _____

Age _____ Date of Birth _____ Gender _____ Height_____ Weight_____

The following questions are designed to help us access your health and training status. It is extremely important for us to know if you have any medical conditions which may affect your testing process or your participation in exercise. Please take the time to answer these questions accurately.

Medical History

YES **NO** In the past five years have you had:

( ) ( ) 1. Pain or discomfort in chest, neck, jaw, or arms

( ) ( ) 2. Shortness of breath or difficulty breathing at rest or with mild exertion (e.g., walking)

( ) ( ) 3. Dizziness or fainting

( ) ( ) 4. Ankle edema (swelling)

( ) ( ) 5. Heart palpitations (forceful or rapid beating of heart)

( ) ( ) 6. Pain, burning, or cramping in leg with walking

( ) ( ) 7. Heart murmur

( ) ( ) 8. Unusual fatigue with mild exertion

Have you ever had:

( ) ( ) 9. Heart disease, heart attack, and/or heart surgery

( ) ( ) 10. Abnormal EKG

( ) ( ) 11. Stroke

( ) ( ) 12. Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)

( ) ( ) 13. Asthma or any other pulmonary (lung) condition

( ) ( ) 14. Heart or blood vessel abnormality (e.g., suspected or known aneurysm)

( ) ( ) 15. Liver or kidney disease

( ) ( ) 16. Thyroid disorder

( ) ( ) 17. Are you currently under the care of a physician?

( ) ( ) 18. Do you currently have an acute systemic infection, accompanied by a fever, body aches, or swollen lymph glands?

( ) ( ) 19. Do you have a chronic infectious disease (e.g. mononucleosis, hepatitis, AIDS)?

( ) ( ) 20. Do you have a neuromuscular, musculoskeletal, or rheumatoid disorder that is made worse by exercise?

( ) ( ) 21. Do you know of any reason why you should not do physical activity?

If you answered yes to any of these questions, please explain.

_____

_____

_____

_____

CAD Risk Factors

YES	NO	DON'T KNOW	
( )	( )	( )	1. Are you a male 45 years of age or older?
( )	( )	( )	2. Are you a female 55 years of age or older
( )	( )	( )	3. Do you have a father or brother who had a heart attack or heart surgery before age 55?
( )	( )	( )	4. Do you have a mother or sister who had a heart attack or heart surgery before age 65?
( )	( )	( )	5. Do you smoke or have you quit in the past 6 months?
( )	( )	( )	6. Do you know your blood pressure? _____/_____ mmHg-Date:
( )	( )	( )	7. What is your total cholesterol? _____mg/dL-Date:
( )	( )	( )	9. Are you taking cholesterol lowering medication?
( )	( )	( )	10. Do you know your HDL cholesterol? _____mg/dL-Date:
( )	( )	( )	11. Is your HDL cholesterol > 60mg/dL?
( )	( )	( )	12. What is your fasting blood glucose? _____ mg/dL – Date:

If you answered yes to any of these questions, please explain.

_____
_____
_____
_____

For Office Use Only

Health-Related Questions

YES NO

( ) ( ) 1. Are you pregnant?

( ) ( ) 2. Are allergic to isopropyl alcohol (rubbing alcohol) or latex?

( ) ( ) 3. Do you have any allergies to medications, bees, foods, etc.? If so please list

_____

( ) ( ) 4. Do you have any skin problems?

( ) ( ) 5. Do you have any other medical condition(s)/surgeries?

( ) ( ) 6. Have you had any caffeine, food, or alcohol in the past 3 hours?

( ) ( ) 7. Have you exercised today?

( ) ( ) 8. Are you feeling well and healthy today?

If you answered yes to any of these questions, please explain.

_____

_____

_____

_____

Training Status Questions

1. Do you exercise vigorously on a regular basis?

   ☐ Yes ☐ No

2. What activities do you engage in on a regular basis?

3. How often per week do you workout?

4. How often do you participate in cardiovascular training (track/swimming workout etc.)?

   Please describe a typical cardiovascular training session.

5. Do you lift weights?

   ☐ Yes ☐ No

6. If yes, how long have you been lifting weights?

7. How often do you participate in resistance/weight training?

Please describe a typical resistance training session.

8. Do you know your bench press 1 repetition max (RM) weight?

9. Do you participate in any other type of physical activity on a regular basis during a week?

If you answered yes, please explain (type of activity, duration of each activity etc.).

10. What is your position?

Medications

Please Select Any Medications You Are Currently Using:

- ☐ Diuretics
- ☐ Beta Blockers
- ☐ Vasodilators
- ☐ Alpha Blockers
- ☐ Calcium Channel Blockers
- ☐ Birth Control
- ☐ Other Cardiovascular
- ☐ NSAIDS/Anti-inflammatories (Ibuprofen, Voltaren)
- ☐ Cholesterol
- ☐ Diabetes/Insulin
- ☐ Other Drugs (record below).

Please list the specific medications that you currently take:

_____
_____
_____
_____

I certify that the information I have provided is complete and accurate to the best of my knowledge.

Date _____ Signature of Subject _____

Date _____ Signature of Witness _____

Office Use Only

____ Low Risk ____ Moderate Risk ____ High Risk

Appendix B.

INFORMED CONSENT FORM

Application of the Predicted Repetitions-to-Failure Rating of Perceived Exertion Scale for the NFL 225-lb Bench Press Test

Purpose and General Information

You are being asked to participate in a research study conducted by Anthony Ratto (Principle Investigator)-and Young Sub Kwon, Ph.D. (supervising staff member). The purpose of this study is to assess how accurately Division II NCAA football players can predict repetitions-in-reserve during the bench press exercise using an absolute load of 225-lbs by comparing predicted repetitions-in-reserve with actual repetitions-in-reserve. This form will explain the study, including possible risks and benefits of participating, so you can make an informed choice about whether or not to participate. Please read this consent form carefully. Feel free to ask the investigators or study staff to explain any information that you do not clearly understand.

What will happen if I participate?

This proposed project was developed based on science and theory in the fields of Exercise Science. All testing will take place in the Student Recreation Center (SRC). When scheduling takes place, you will be asked to refrain from using caffeine, alcohol, and vigorous exercise for 24 hours before each testing session. If you agree to be included in this study, you will be asked to read and sign this consent form. Upon signing, the following will occur:

Day 1: Screening process, paperwork, familiarization, 1 repetition max (1RM) test

- The study will be described in detail and your questions will be answered, then you will fill out all pre-screening forms in a private room in the Human Performance Lab. You will be introduced to the study, the purposes and procedures, and the risks and benefits. You will complete this informed consent, health history and physical activity questionnaires, and the Physical Activity Readiness Questionnaire (PAR-Q) form.
- Your height and weight will be measured

- You will be screened for eligibility for this study based on your answers to the questionnaires and your athletic clearance. If the criteria are not met, you will be excluded from the study.
- You will be asked if you have any soreness or injury to your shoulder, triceps, and chest.
- You will be asked if you have refrained from caffeine and alcoholic beverages in the previous 24 hours.
- You will be verbally instructed on the use of the Repetitions to Failure Scale, and on the general procedure of the study

1 Repetition Maximum (1RM) test and 225-lb bench press test

- You will position your hands on the bar with your usual grip. You will use a closed grip.
- You will be required to perform a warm-up of 1 set of 10 repetitions of estimated 1RM followed by 3 minutes of rest. The second set will be performed with 70% of estimated 1RM and 5 repetitions will be completed followed by a 3 minute rest period. 3 repetitions will be completed at 80% of estimated 1RM followed by a 3 minute rest period. The final set of 1 repetition will be completed with 90% of estimated 1RM followed by a 3 minute rest period. If a 1Rm attempt is successful, you will add 10-20lbs and attempt another repetition. If an attempt is unsuccessful, you will decrease weight by 5-10lbs and attempt another repetition. 1RM testing should finish within 6 repetitions.

Day 2: NFL 225-lb bench press test

- You will be asked if you have any soreness or injury to your shoulder, triceps, and chest.
- If you are experiencing any soreness, then the session will be postponed one additional day.
- You will be asked if you have refrained from caffeine and alcoholic beverages in the previous 24 hours.
- You will position your hands on the bar with your usual grip. You will use a closed grip.
- You will be required to perform a warm-up of 10 repetitions at 50% of 1RM followed by a 3-minute rest period, 1 sets of 5 repetitions at 70% of 1RM followed by a 3-minute rest period, and 1 repetition with 225-lbs.

- After the warm-up, you will have 5 minutes of rest before performing one set to concentric failure with 225-lbs. Before the set is begun, you will be asked how many repetitions you will be able to complete before failure. You will be asked again after the fourth, eighth, twelfth, sixteenth, and twentieth repetitions if possible.

What are the possible risks or discomforts of being in this study?

Every effort will be made to protect the information you give us as well as minimize any risk by allowing proper warm-up. As with any research, there may be unforeseeable risks. These risks include muscle soreness, muscle fatigue, and common injuries and issues associated with exercise.

For more information about risks, contact the Principal Investigator, Anthony Ratto.
(510) 846-6829
agr24@humboldt.edu

How will my information be kept confidential?

Your name and other identifying information will be maintained in files, available only to authorized members of the research team for the duration of the study. For any information entered into a computer, the only identifier will be a unique study identification (ID) number. Any personal identifying information and record linking that information to study ID numbers will be destroyed when the study is completed. Information resulting from this study will be used for research purposes and may be published; however, you will not be identified by name in any publications.

Will I be paid for taking part in this study?
There will be no compensation.

Can I stop being in the study once I began?
Yes, you can withdraw from this study at any time without consequence.

Protected health information (PHI)
By signing this consent document, you are allowing the investigators and other authorized personnel to use your protected health information for the purposes of this study. This information may include: height, weight, age, %body fat, and health and fitness related items on the questionnaires. In addition to researchers and staff at the Human Performance Lab (HPL) at Humboldt State University (HSU) and other groups

listed in this form, there is a chance that your health information may be shared (re-disclosed) outside of the research study and no longer be protected by federal privacy laws. Examples of this include disclosures for law enforcement, judicial proceeding, health oversight activities and public health measures.

Right to Withdraw
Your authorization for the use of your health information shall not expire or change unless you withdraw or change that information. Your health information will be used as long as it is needed for this study. However, you may withdraw your authorization at any time provided you notify the Humboldt State University investigators in writing. To do this, please contact:

Anthony Ratto
(510) 846-6829
agr24@humboldt.edu

Please be aware that the research team will not be required to destroy or retrieve any of your health information that has already been used or shared before your withdrawal is received.

Refusal to Sign
If you choose not to sign this consent form, you will not be allowed to take part in the project.

What if I have questions or complaints about this study?
If you have any questions, concerns, or complaints about this study, please contact Young Sub Kwon, Ph.D. (faculty adviser) at 707.826.5944 from Monday thru Friday 8am - 5pm. (or at 505-350-4345 after hours). If you would like to speak with someone other than the research team, if you have any concerns with this study or questions about your rights as a participant, contact the Institutional Review Board for the Protection of Human Subjects at irb@humboldt.edu or (707) 826-5165.You may email the Institutional Review Board (IRB) at irb@humboldt.edu. The IRB is a group of people from Humboldt State University and the community who provide independent oversight of safety and ethical issues related to research involving human subjects.

Liability
No compensation for physical injury resulting from participating in this research is available.

Consent and Authorization

You are making a decision whether to participate in this study. Your signature below indicates that you read the information provided (or the information was read to you). By

signing this Consent Form, you are not waiving any of your legal rights as a research subject.

Sincerely,

Anthony Ratto, B.S., CSCS
(510) 846-6829

I have read and had the opportunity to ask questions and all questions have been answered to my satisfaction. By signing this consent form, I agree to participate to this study and give permission for my health information to be used or disclosed as described in this consent form.
A copy of this consent form will be provided to me.

_____ _____
Signature of participant Date