SELF-CORRECTION OF DEADLIFT FORM UTILIZING REAL TIME VISUAL FEEDBACK INFORMATION

By

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Abstract: Practice in front of mirrors to enhance performance through visual feedback and knowledge of performance is common in athletics that require precision and fine body control like dance and gymnastics. It is also very common to enhance motor learning of a task through evaluation of performance after the completion of a motor task such as weight lifting. Competitive weightlifters often utilize recordings of their lifts to improve future performance by evaluating form, technique, speed of movements, and several other factors that influence the quality of the lift. Studies have been performed to analyze the effect of the use of mirrors during the performance of a power-clean, but no known study has been completed evaluating the use of a system that provides concurrent augmented visual feedback of a weightlifter's sagittal plane. The visual feedback system utilized in this study projects a real-time video image of the subject's sagittal plane to a screen directly in front of the subject allowing the subject to view their performance as they complete a deadlift. Each subject performed two deadlifting sessions, one utilizing concurrent visual feedback and one without. During each session the subject achieved a 1RM for the deadlift then performed successive repetitions at 90% of their 1RM to determine if the use of concurrent visual feedback effected maximum force production or the subject's ability to self-correct discrepancies in their form allowing them to complete more repetitions with proper form as they fatigue. Statistical analysis showed a significant increase in maximal strength when concurrent visual feedback was provided; no significant difference was seen concerning the performance of repeated efforts at 90% 1RM.

Introduction: In resistance training and sports, the efficient development of motor skills is vital for enhancing performances and protecting athletes. Optimal motor learning can be accomplished when athletes are able to utilize both intrinsic and extrinsic feedback in order to correct or modify their movement patterns (1). The integration of intrinsic and extrinsic feedback has been termed augmented feedback and can be delivered either during or after the movement. Feedback delivered and processed during the movement is considered concurrent feedback (1). It has been shown that concurrent feedback is effective at improving motor learning in the early stages of skill development with complex motor task. Studies have found that concurrent feedback had a greater effect than terminal feedback and no feedback in performing simple motor tasks (2,3). However, the efficacy of concurrent augmented visual feedback with a complex resistive motor task has not been established. In rehabilitative settings continuous feedback and knowledge of performance are viewed as appropriate for the early stages of motor learning, and that as the learner progresses, feedback should be provided less often and should shift more to knowledge of results (4). Knowledge of performance is feedback given concurrently during the performance of a task and knowledge of results is feedback provided after the completion of the task.

It is common to practice in front of a mirror for activities such as gymnastics, dance, and other sports in order to gain visual feedback to improve performance. The use of mirrors is also commonly used in weight training to assess form and positioning in the frontal plane. However, there are limitations associated with the use of mirrors; they can only be used to view oneself in a "head-on" view or at an oblique angle between the frontal and sagittal planes. Another limitation during motor training is reflected images are flipped and can cause confusion.

It is commonplace for weight lifters to evaluate performance by utilizing videos of themselves performing lifts, however performance is most often viewed after completion of the lift. Concurrent visual feedback, like the system used in this study should allow lifters to analyze, critique, and adjust technique and body position prior to, during, and throughout the performance of a lift. This method of visual feedback delivery allows the subject to evaluate their body position and form prior to initiation of the “pull” phase and throughout the completion of a lift by augmenting proprioceptive and intrinsic information with real time visual information of themselves in the sagittal plane.

Concurrent augmented feedback has been shown to enhance learning, and learner controlled self-observation has been shown to be advantageous for the acquisition of motor skills (5). One study showed a significant difference in execution of the power clean when using a mirror for visual feedback (6). However, other studies have shown that concurrent feedback can be detrimental to performance secondary to added distractions and the correction of task irrelevant errors (7). Thus the effectiveness of concurrent visual feedback may depend heavily on the complexity of the visual information itself.

The deadlift is one of the most well-known and widely used lower extremity and trunk strengthening resistive exercises around the world (8). The deadlift is a complicated resistance exercise that requires certain positioning, however it does not require complicated successive steps such as the clean and press. It also allows the subject to maintain visual contact with a forward target throughout the lift without affecting technique. Additionally, forces produced by lifters during the performance of a deadlift are heavily influenced by positioning and leverages applied by the lifter. Therefore, minor adjustments to a lifters positioning prior to and throughout the pull can be of large consequence both considering the lifters health and safety and overall athletic performance of the lift. For these reasons the deadlift was selected as the motor task to be used for evaluating the efficacy of concurrent visual feedback during a complex resistive task. The deadlift exerts great forces on the body and requires appropriate techniques to perform safely and to decrease the risk of injury to the lifter. Injury while performing the deadlift often occurs as a result of poor form. Appropriate feedback and proper exercise form has been shown to decrease injury risk (9). The use of concurrent visual feedback similar to what was utilized in this study could prove useful to decrease the likelihood of injury associated with the lift by improving technique.

Another potential advantage of feedback systems like this is providing the lifter with accurate and consistent feedback without someone to monitor technique. This feedback could reduce the fear of injury making beginner and intermediate lifters feel more comfortable with resistive training. Decreasing the risk of injury would prove beneficial to both the athletes and everyday recreational lifters that performs this movement. If found to be a safe and effective way of improving a subject's' form with this particular exercise, concurrent visual feedback systems similar to the one used in this study could have widespread impacts in both strength and conditioning and rehabilitation settings. It is likely that the use of concurrent visual feedback would have a similar effect with other movements. The study also examined the subjects' ability to self-correct form while performing a deadlift by utilizing the concurrent visual feedback provided. The aim of this study was to evaluate whether providing concurrent visual feedback of a participant performing a conventional deadlift would impact the subject's form, which could be objectively measured by an increase in maximal weight deadlifted or by an increase in repetitions achieved with submaximal weight in a state of fatigue.

Methods: Participants: Approval to commence this study was provided by the International Review Board at Angelo State University prior to recruitment of subjects. Subjects were recruited through the use of fliers located throughout the local campus and a mass email to local collegiate students and faculty. All participants agreed to participate and signed an informed consent agreement which followed the guidelines of the local review board. Inclusion criteria was as follows: individuals have been weight training for at least 18 months and are able to deadlift a one rep maximum (1RM - the maximum amount of weight they can lift for one repetition) equivalent to bodyweight for females and 1.5 times bodyweight for men. Participants were excluded from the study if able to complete a one rep max equivalent to two and a half times bodyweight for females and three times bodyweight for men. Subjects were required to fill out an intake sheet concerning these criteria and to provide their estimated 1RM prior to their participation to ensure that all criteria was met. The inclusion and exclusion criteria were used to ensure that participants met the definition of an intermediate lifter to create a group with similar characteristics and to minimize health and safety risk of the subjects during the study (10).

Study Design: This study utilized a repeated measures crossover design in order to reduce order effects and allow each subject to serve as their own "control" (11). Participants were randomly assigned into two groups based on order of participation in study and gender. One group performed their first session with video feedback and then progressed to no video feedback in their second lifting session, while the other group started without visual feedback and progressed to using the visual feedback system during their second lifting session. The study consisted of two groups of 4 subjects with 2 males and females each. This study design was utilized in order to diminish the possibility of subjects showing improvement due to factors other than the visual feedback system.

Procedure: Subjects were required to complete a pre-screening form examining the subjects' health, experience with performing the deadlift, and estimated one-rep maximum in addition to meeting all inclusion criteria. Next, the design and goals of the study were explained to the subjects individually. The participants were required to review a handout outlining the specific techniques that they were to utilize during their subsequent lifting sessions and the specific guidelines of the study. The handout describes the deadlift form used in the study based on guidelines established in the book *Starting Strength* by Mark Rippetoe, which are utilized by international exercise performance companies like Crossfit (8). The subjects were also given the opportunity to ask the researchers questions about the guidelines prior to beginning the study. Subjects were required to agree to the guidelines of the study and score at least 80% on a quiz over the techniques they were to use for the lift. Incorrect responses on this quiz were reviewed with the subjects. Both the handout and the quiz can be seen in the Appendix C. Next, the subjects' height, weight, hamstring lengths (popliteal angle), and neural tension (Slump test) were evaluated and recorded. Participants were also visually screened by the researchers for any skeletal deviations which could affect performance, including leg length discrepancies and scoliosis. Hamstring length and neural tension was evaluated using the straight leg raise test and slump test respectively to test if either hamstring length or neural tension may be related to any lifting restrictions that might be discovered (12).

To begin each exercise session, the subject was first run through a general warm up routine to decrease the risk of injury which can be seen in Appendix A - Table 1. Subjects were then taken through a specified deadlift warm-up routine with weights determined by their estimated 1RM prior to the initiation of finding the subjects' true 1RM.

During each session the lifter worked up to a 1RM , using the American College of Sports Medicine's standards for establishing a 1RM (13). In order for the 1RM attempt to count as a successful lift the subject was required to begin in the correct starting position, maintain the appropriate technique throughout the lift, and fully lock out the lift. Studies demonstrate excellent inter-rater reliability in determining 1RM even when considering the subjectiveness of evaluations of form (14). Particular attention was paid to the degree of lumbar rounding; the lift was considered failed if lumbar spine was subjectively determined to be rounding by the researchers. Once the lifter stated that they had reached their max or their max was determined by the researchers, a 5 minute rest ensued before the initiation of the next aspect of the study. To adequately evaluate the effects of the concurrent visual feedback system on the deadlift it was necessary to evaluate the impact on both max and submax performance. In order to do this the subject was instructed to perform one deadlift at 90% of their 1RM every minute on the minute (EMOM) at the end of their 5 minute break following achieving their 1RM. Subjects continued to lift 90% of their 1RM EMOM for as long as they could maintain form that was deemed adequate by the researchers, or until the lifter could no longer complete the lift, or until 15 successful lifts had been performed. 90% of 1RM was chosen as the load because it is considered the minimum acceptable competition weight that requires the lifter to utilize maximal motor units (15). Performing the lifts at this weight should have ensured that the subject must utilize correct form in order to achieve the lift. The weight should also have been adequate to fatigue the subjects and stress their form, but with the work to rest ratio (5:55 seconds) the subject's endurance was not taxed (9,16). The goal of this aspect of the study was to challenge the lifters form under strain and not from endurance, but without allowing excessive recovery time.

When the researchers deemed that sufficient form was not maintained or achieved during EMOM lifting based on expert opinion through visual observation, the lifter was given one verbal warning. If any of the following repetitions were not satisfactory, then the current testing session was terminated. During data collection the quality of the lifts according to the guidelines of the study were determined by two physical therapy students who are Certified Strength and Conditioning Specialists with substantial experience executing and coaching the deadlift.

A video camera was mounted on a tripod approximately 8 feet from the subjects left side and was aligned directly in line with the barbell in order to film the subject directly in the sagittal plane in a mediolateral direction. Every 1RM attempt and lift at 90% of 1RM was filmed in order to be evaluated with video analysis software to provide an objective mean of determining the subjects form and technique on each lift.

During the session in which subjects utilized the concurrent visual feedback system the only changes that were made was the addition of a 22 by 28-inch screen directly in front of the lifter and slightly below the line of sight when the lifter stands erect with the head in a neutral position. The screen was located approximately 6 feet in front of the barbell at the subject's midline. Real-time video from the video camera at the subject's side was projected onto the screen allowing the subject's to view themselves in the sagittal plane in real time while maintaining a forward head position (see Appendix C). The two lifting sessions were identical other than the use of the concurrent visual feedback system. The two lifting sessions were separated by 6-9 days. Subjects were asked to refrain from deadlifting during this recovery time, and not to lift the day before or day of their 2nd session. At the completion of each subject's second lifting session they were e-mailed a link to an anonymous online survey about their views of the use of the concurrent visual feedback system.

Outcome Measures: The three key outcomes assessed in this study were the number of successive repetitions completed with proper form at 90% of 1RM, the max weight lifted, and the 1RM as a percentage of bodyweight in each setting, with concurrent visual feedback and without. Kinovea 0.8.15™, a video analysis software, was used to determine when form failure actually occurred using pre-set objective standards, which can be seen in more detail in Table 2. Kinovea was used to analyze video recordings of each 1RM attempt and each EMOM lift performed by the subjects in both trials. All film analysis was completed after all subjects had completed both sessions of the study. The pre-set standards for calculating the number of successive EMOM lifts at 90% 1RM utilized a point system and when a lifter had accrued a total of four points the last successful lift was considered their number of successful repetitions with proper technique and form. For example, if the lifter was determined to have had excessive lumbar rounding (2 points) on lift number 11 and 12 (4 points total) then lifter would have been scored as completing 11 lifts. This scoring system can be seen in Appendix A- Table 2.

Using the Kinovea system, ten degrees of lumbar rounding was established as the cut-off value for determining when lumbar rounding was excessive enough to consider the lift failed secondary to the lifter not maintaining the appropriate form and motor pattern. The degree of lumbar rounding was assessed using Kinovea, for specific criteria see Appendix A- Table 2. Criteria for a successful lift and 1RM can be seen Appendix C in the take home points section. In order to determine if the subject attained the correct starting position they were asked to maintain the position for 3 seconds. If the correct starting position was not attained the lift was considered a failed lift. To assist the researchers in determining if the appropriate starting position was achieved by the lifter a stationary visual reference line was created. This device can be seen in the images of the setup and equipment in the Appendix C. The angle of this reference line was set 12 degrees in front of vertical. The device was placed a few inches from the right side of the barbell with its axis over the center of the barbell. This reference line allowed the researchers to see in both real-time and during video analysis of the appropriate latissimus dorsi angle, shoulder relation, and spinal alignment was achieved in the starting position of the lift.

Statistical Analysis: Data was analyzed utilizing SPSS version 21 (IBM, Chicago, IL). Baseline data was assessed for normality using a Shapiro Wilk's test. Demographic data was assessed utilizing descriptive statistics and Pearson's *r* during initial data exploration. Dependent variables included: number of repetitions performed, maximum weight lifted and percent of bodyweight maximum. Paired *t* test analysis was performed to assess differences between visual feedback and no visual feedback. Final testing included a Repeated Measures ANOVA analysis to test for an interactive effect of feedback order in this crossover design.

Results: Eight subjects were included in the analysis of objective data; Table 3 provides descriptive demographic findings of these subjects, with no significant differences noted between groups. According to the normality of variables, there were not any outliers in this pilot study.

Paired t test analyses demonstrated a significant increase in the maximum weight lifted 13.75±12.75 pounds ($p = .019$) and the max as percentage of bodyweight 7.99%±7.99% ($p = .026$) during the visual feedback session (Table 4). Individual and mean results can be seen graphically represented in Appendix B. Repeated Measure ANOVA revealed no interaction between group (feedback order) and time for any of the dependent variables measured indicating no effect of feedback order/placement. Time was not shown to be a significant factor amongst the groups. Repeated effort did not show a significant difference; the slump test and hamstring length tests did not show a statistically significant difference amongst the two testing groups.

According to the survey, 80% of subjects were moderately to maximally comfortable in performing a 1RM deadlift (DL) prior to the study. 73.3% of subjects used the screen the entire time. 86.7% of subjects disagreed or strongly disagreed that the visual feedback hindered their performance of the DL. 86.7% felt that the visual feedback enhanced their performance. 86.7% preferred performing the DL with visual feedback 73.3% felt safer performing the DL with visual feedback. Even if the subjects did not feel that the visual stimulus was beneficial to them personally, 100% of the subjects felt that the visual stimulus would have been helpful to them when they were first learning the deadlift. This data can be found in Graphs A-G, and the complete survey can be viewed in the Appendix B.

Discussion: A number of different variables that affected the outcomes of this pilot study deserve to be investigated and discussed further. In regards to the mean demographics represented in this study, no real differences were seen between the groups tested and no outliers were found. The subjects were selected from a group of healthy, generally active, athletic lifters that match up well with the demographics of other studies which investigate deadlift training in similar populations (17). Though some variation is expected, this study found little variation with most individuals performing similarly and achieving similar results.

Because the subjects had been performing the deadlift prior to the supervised performance during the study based on the inclusion criteria, their participation should not have placed them at an increased risk of injury any more than their normal lifting regimen. An intermediate lifter still requires form cues and is working towards improving a movement pattern (10). A beginning lifter was not desired for this exploratory study because a level of competence with the lift needed to be achieved so that there was relative consistency within the movement. On the other hand, a competition lifter would have an ingrained movement pattern and difficulty with changing their form (18). Intermediate level lifters were selected as the population to be tested due to the hypothesis that video feedback would have a greatest impact on this group.

A substantial difference was seen in the max strength of the lifters when they were allowed to utilize the concurrent visual stimulus. Based on the responses from the subjects, the most likely reason for them being able to increase their maximal load so substantially is that they were able to get into a more effective pulling position and/or had increased confidence with the new position, either because it felt safer, or because they could visually identify it as a more efficient position to pull from. This is supported in sport psychology; studies have determined that knowledge of successful past performances has a strong link between appropriate task selection, improved performance, and better self-efficacy (19).

It stands to reason that percentage of bodyweight lifts were also increased because this variable utilizes the maximum weight that the individual could lift in a ratio to their bodyweight. Since the bodyweight of participants was varied, examining relative strength helped to simplify the data. Establishing that relative strength ratio was within a certain range indicated that the lifters intermediates (17).

No significant difference was seen between concurrent visual feedback and non-visual sessions concerning the amount of repeated submaximal repetitions. The participants often pulled personal records when utilizing the visual feedback or at least substantially increased what they could do as compared to when they had no visual feedback, thus the athletes could not maintain such an increased load during the repetition work since the 90% of 1RM increased along with the 1RM. Since most subjects had an average increase of 13.75±12.75 pounds in weight than what they normally deadlift without visual stimulus (and that many lifters were doing EMOM lifts during the visual session with weights that were previously 1RM weight without visual stimuli), their bodies simply were not acclimated for such a large increase in workload during the EMOM section. Even though an increase in total load was seen during the max-out session, there is not an immediate physiological turnover that allows the lifter to deadlift such a large proportion of maximum weight many times in a fatigued state. One study found that although work capacity increases as maximal strength increases it takes up to 12 weeks to see proportional changes (20). This new motor pattern has not had time to be cemented into the user's motor abilities (21), so there is a greater deal of muscular demand on the athlete to maintain this new form than to revert back to their old way of lifting. This new way of lifting is more demanding on their body, in addition to the ligamentous, tendinous, mitochondrial, and muscular changes that must occur in order for the lifter's body to adapt and improve with this sort of demanding repeated effort. It is worth noting that 90% of the session max was utilized during the experiment in order to accommodate for daily changes/abilities with each lifter and keep the testing process as standardized as possible. Future studies may choose to keep the submaximal EMOM session at a singular weight instead of the weight depending on daily/session 1RM.

The slump test and hamstring length assessments were included because they would potentially predict a muscle length insufficiency that could lead to the subject being unable to get into the best pulling position. Studies have shown strength declines after stretching but is not affected by neural tension stretches, possibly because neural tension has less of an impact in the pulling position than does muscle length (22). Therefore, it was suggested that those subjects with adverse muscle or neural involvement might put themselves in less efficient positions since their muscles and nerves were stretched further the more they tried to force themselves into the correct starting position. There was not a correlation between those that had a positive slump test or decreased hamstring length and those that saw greater improvement or detriment during testing. Though there may not be a direct correlation, the understanding that flexibility does not equate to mobility may help to eliminate these issues from being the first areas to attack when trying to fix poor deadlift technique. If what was found in this pilot study is true-that neural or muscle shortening does not affect the pull and/or the ability to attain the best starting position- then the issue a lifter is having in achieving the best position may be a neuromuscular recruitment issue, which could potentially be fixed with concurrent visual feedback. Thus, the fact that those with adverse neural/muscle length tension were able to get just as much effect from the visual stimulus as those that did not have this constraint may signify that the visual feedback that they got was able to help them overcome a physiological deficiency simply by neuromuscularly recruiting different muscles to pull themselves into better positions. Research supports this idea; in a study performed on rugby players that had a strained hamstring, it was found that hamstring length and EMG activity are not related to a positive Slump test, revealing that although discomfort may keep someone from stretching or activating muscles, this input can be tampered down and ignored by the subject to achieve muscular contraction (23).

As mentioned in the results section, order of testing was determined to not be a significant factor. This demonstrates that whether the visual feedback testing session took place first or second the subject improved with maximum effort deadlifts when utilizing visual feedback. This means that the learning effect was minimized, and ensures that the subjects improved because of the testing scenarios, not as result of learning.

Based on the effects seen in this pilot study, additional studies may choose to utilize visual feedback with beginner level athletes. In theory, utilization of the techniques used in this pilot study may prove beneficial for the initial stages of motor learning when extrinsic feedback is the most important (4); feedback should become more intrinsic as athletes progress, so similar or increased benefit might be expected with novice lifters.

One demographic criteria that was not identified was training age. Training age is defined as how long an individual has been training, and often includes components like sport-specific training, general training, and lifestyle (24). Though having this information could have improved the identification of novice, intermediate, and advanced lifters, it would be very difficult to establish appropriate parameters for determining a lifter's training age, since determining a definite starting place is challenging. More importantly, the inclusion criteria were based upon a reliable source and the data was normalized with no outliers, so it can be concluded with that the lifters were appropriately identified as intermediates.

Another area that could have been analyzed during this experiment was the performance of a lumbar range of motion (ROM) screen, studies have shown that hip movement is correlated to lumbar joint range in stoop lifting (25). This could have been done utilizing goniometry and manual passive movement of the lower extremities to identify that no aberrant motion was occurring, or simply could have been achieved with the athlete performing functional tasks, like the ability to bear crawl without extraneous pelvic movement (26). This could have been used as an adjunct to eliminate other problem areas that may have been limiting the subject in deadlift ability in addition to neural tension and hamstring length. Research has already shown that hamstring extensibility effects lumbar and pelvic ROM (27).

This pilot study does have direct and indirect carryover into the field of physical therapy. First, physical therapists often work with athletes, whether recreational or professional, so being able to understand a common exercise that this group of people performs on a more technical level increases the knowledge base of the therapist. Second, understanding the impact of visual feedback is important for the teaching process and can be used to increase the client's confidence in their movement pattern and performance of the movement itself (28). Finally, the lower level possibilities of application for this project would likely have more direct correlation to therapy. Examples of future research could be bodyweight squatting, hip hinging, body mechanics while picking up objects, bicycling mechanics, running mechanics, and any other movements where knowledge of posture in the sagittal plane could be beneficial.

The subjective questionnaire that the lifters answered proved to yield interesting and overwhelmingly positive results. It is clear that the majority of subjects preferred to perform the sessions with visual feedback, felt that it was easy to incorporate the information, and felt safer when they performed the deadlift with visual feedback. Additionally, subjects felt that utilizing visual feedback in the manner presented in this project earlier in their training age would have been beneficial. Future studies may choose to look at how this study may be used with beginner lifters and if they are able to receive benefit from its incorporation into their training cycles.

Study limitations: Due to technical problems, the visual data of 7 of the 15 original subjects was lost. Therefore, they could not be included in the data analysis of changes in 1RM and sub-maximal repeated efforts. However, their subjective data was utilized since performance ability with the different feedbacks had no bearing on that data set. Due to the small size of the research team, the same two students had to perform the pre-screening, instructional session, and testing cycle. Another uncontrollable factor was the motivation of the subjects; performance was likely impacted by motivation and mood. The study was also performed in a busy gym setting that could have been a distraction to the subjects. Thus, fear of the Hawthorne Effect is a valid one, but all participants were subject to the same environment (29).

Conflict of interest**:** None declared. This study was not supported by any grants, but was formulated to meet program requirements for the Angelo State Physical Therapy Department.

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Appendix A: Tables

Appendix B: Graphs

Appendix C: Forms

References

Appendix A

Table 1:

Standardized Warm-up Routine	
Stationary Bike	5 Minutes
BW Squats	x 20
Push-ups	x 10
Leg Lunges	x 20
Arm Circles	x 15
Crunches	x 20
Deadlift at 40% of estimated 1RM	10 Reps
Deadlift at 60% of estimated 1RM	5 Reps
Deadlift at 70% of estimated 1RM	4 Reps
Deadlift at 85% of estimated 1RM	3 Reps

Table 2:
Standards used for the evaluation of footage

Movement Error	Deduction
Improper starting position	2 points
Hips raise first during pull phase	1 point
*Lumbar rounding (>10 degrees)	2 pints
Can not complete lift	4 points

*****Measured from the posterior aspects of approximately the last thoracic vertebrae to the lumbrosacral joint with the axis at the most posterior aspect of approximately the L3 vertebrae.

Table 3:

Group Demographics					
		N	Mean	Std. Deviation	Std. Error Mean
HT (inches)	visual first	4	66.2500	4.42531	2.21265
	non visual	4	72.5000	.57735	.28868
WT (lbs.)	visual first	4	139.5000	24.18677	12.09339
	non visual	4	199.5000	20.24022	10.12011
BMI (kg/m^2)	visual first	4	22.3300	3.07249	1.53625
	non visual	4	26.6900	2.75486	1.37743
AGE (years)	visual first	4	25.0000	1.41421	.70711
	non visual	4	25.0000	4.54606	2.27303
HAMSTRING LENGTH LEFT (degrees)	visual first	4	162.5000	5.00000	2.50000
	non visual	4	158.0000	6.78233	3.39116
HAMSTRING LENGTH RIGHT (degrees)	visual first	4	161.7500	4.71699	2.35850
	non visual	4	156.7500	9.53502	4.76751
SLUMP LEFT LEG	visual first	4	.7500	.50000	.25000
	non visual	4	.5000	.57735	.28868
SLUMP RIGHT LEG	visual first	4	1.0000	0.00000	0.00000
	non visual	4	.5000	.57735	.28868

Table 4:

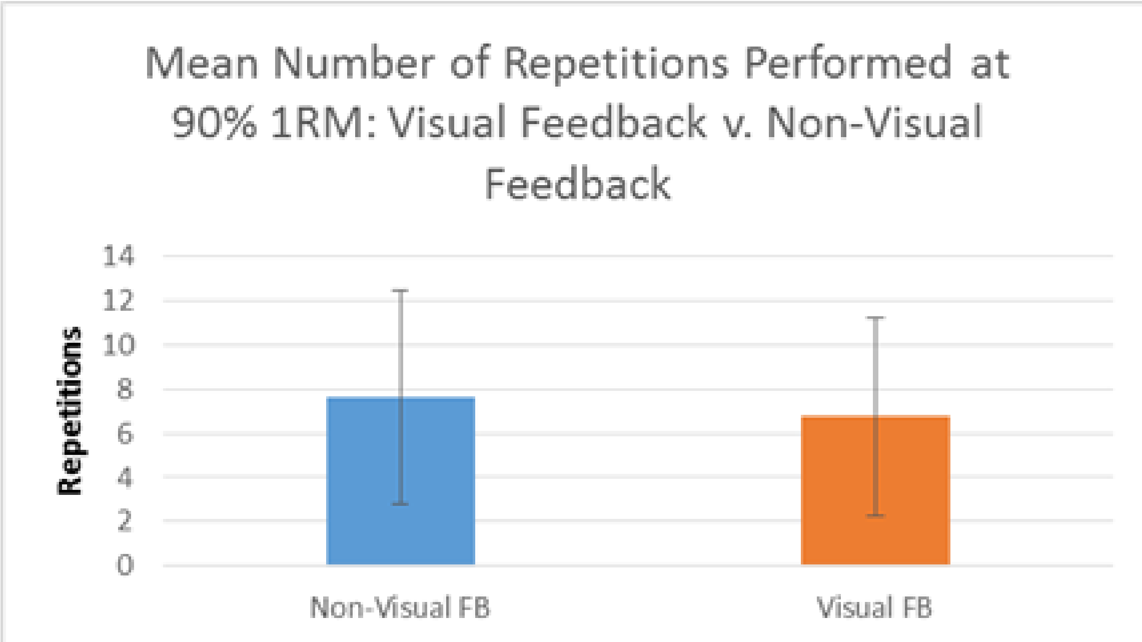
Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	Interval of the Lower	Interval of the Upper			
NVREPS - VFBREPS	.87500	4.64258	1.64140	-3.00630	4.75630	.533	7	.610
NVMAX - VFBMAX	-13.75000	12.74755	4.50694	-24.40722	-3.09278	-3.051	7	.019
NVPCT - VFBPCT	-7.98750	7.99740	2.82751	-14.67349	-1.30151	-2.825	7	.026

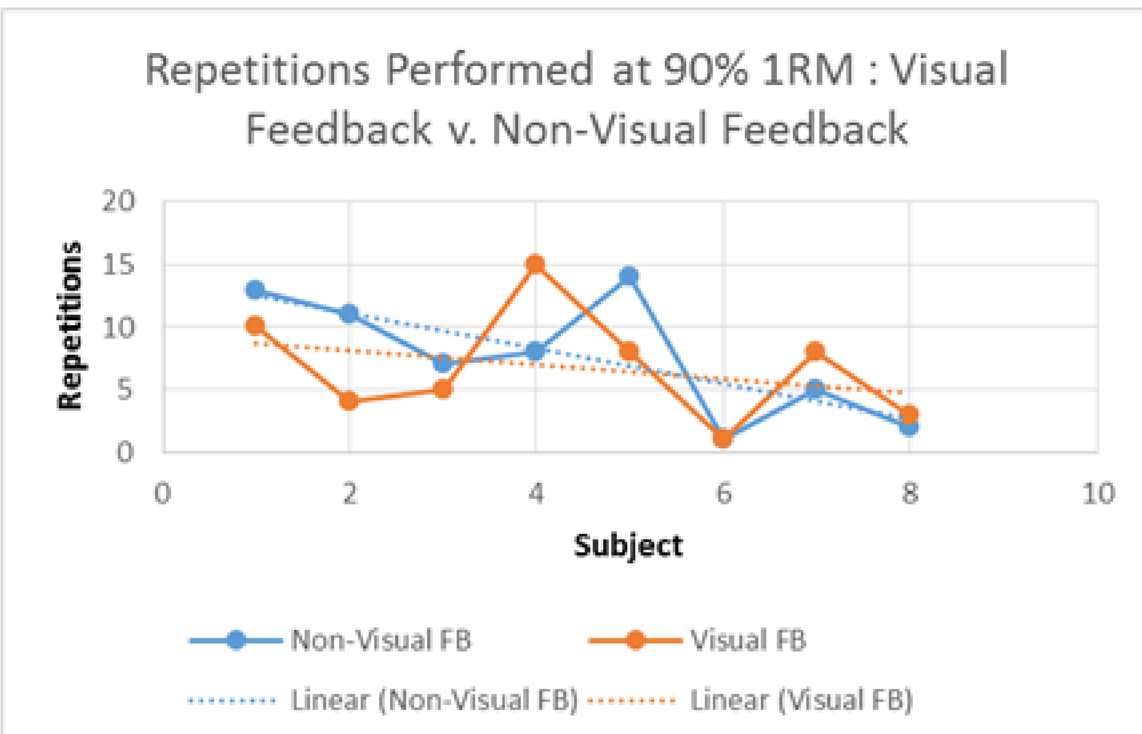
Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
NVREPS	7.6250	8	4.83846	1.71065
VFBREPS	6.7500	8	4.46414	1.57831
NVMAX	312.5000	8	131.44798	46.47388
VFBMAX	326.2500	8	133.49024	47.19593
NVPCT	179.2250	8	41.78454	14.77307
VFBPCT	187.2125	8	41.89574	14.81238

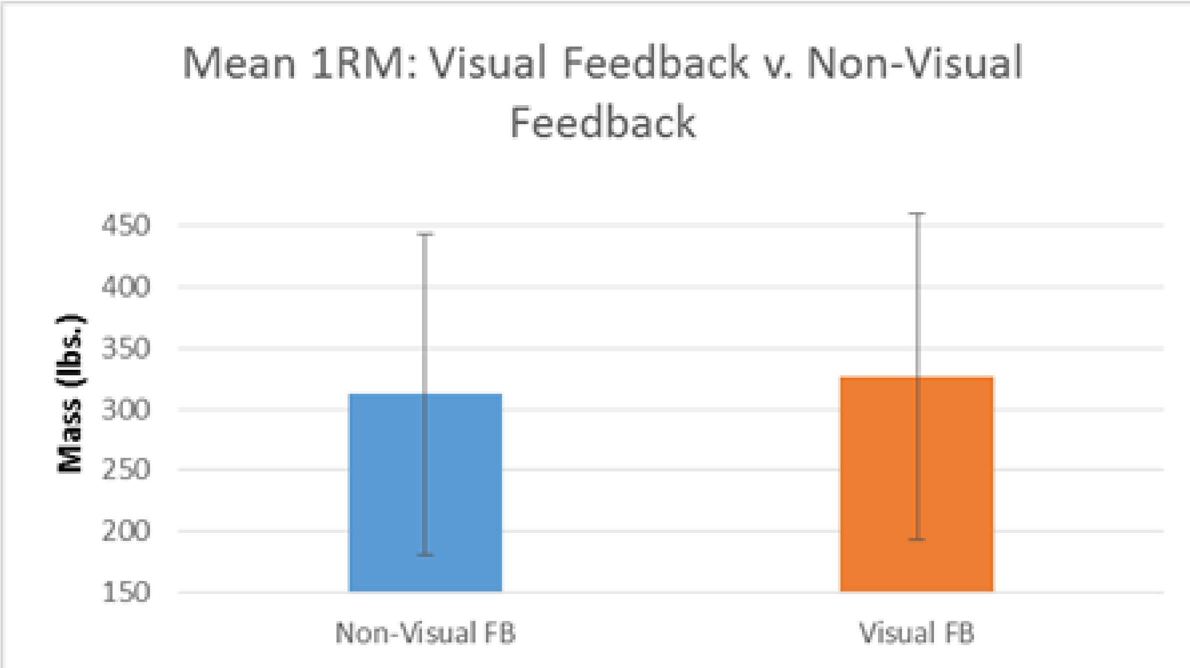
Appendix B

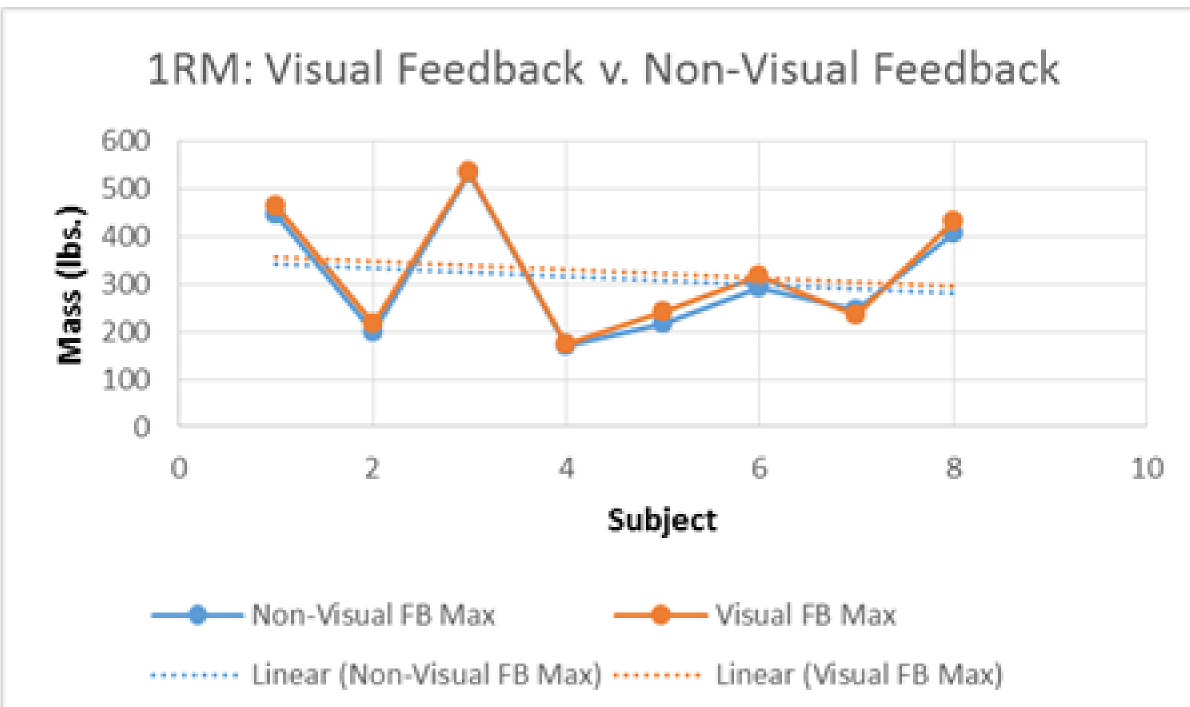


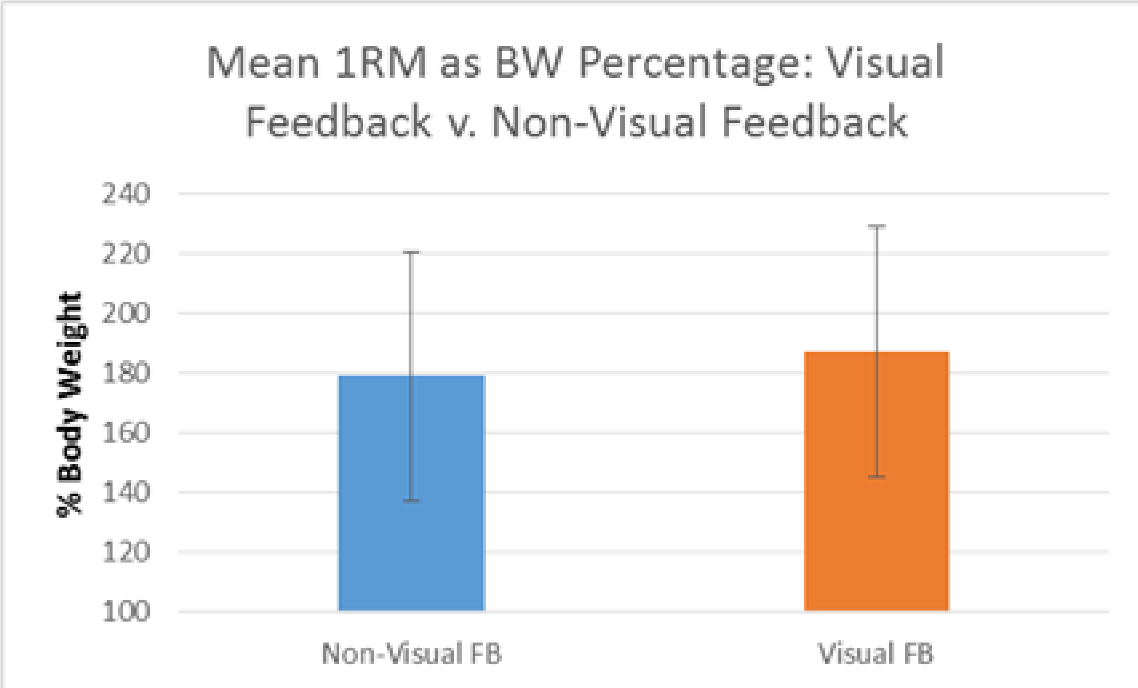
Mean Number of Repetitions Performed at 90% 1RM: Visual Feedback v. Non-Visual Feedback
Repetitions
0
2
4
6
8
10
12
14
Non-Visual FB
Visual FB



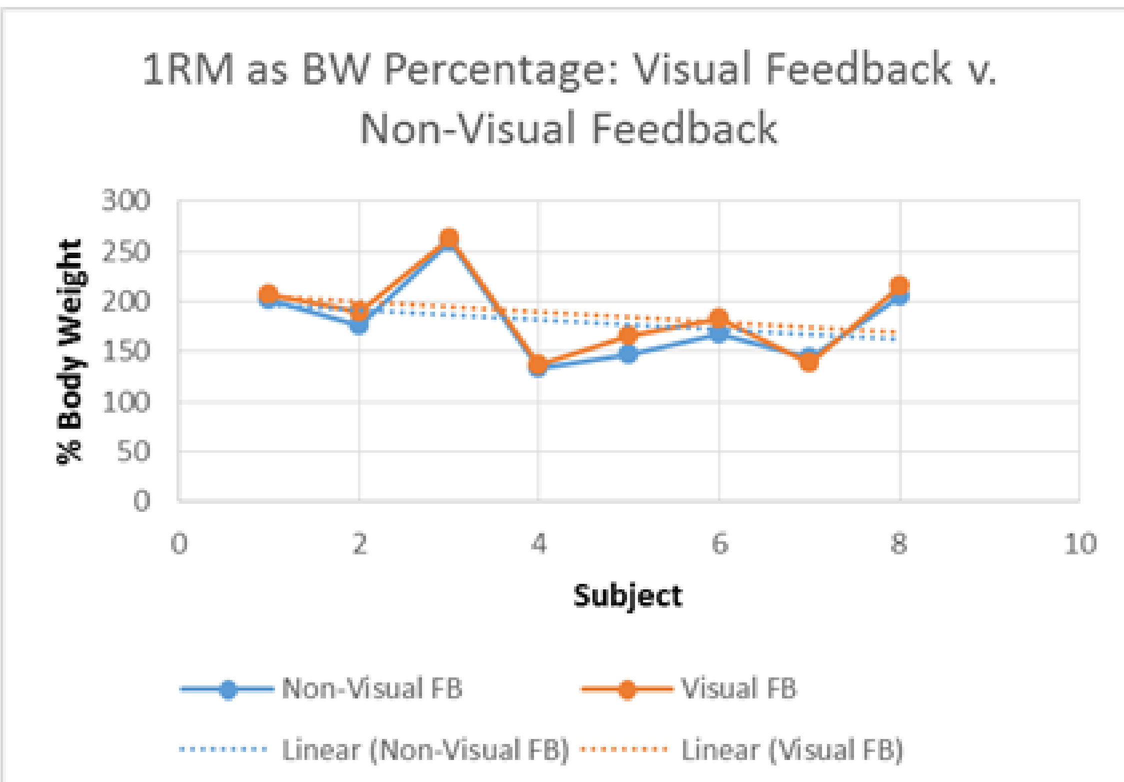
Repetitions Performed at 90% 1RM : Visual Feedback v. Non-Visual Feedback
Repetitions
0
5
10
15
20
Subject
0
2
4
6
8
10
Non-Visual FB
Visual FB
Linear (Non-Visual FB)
Linear (Visual FB)


Mean 1RM: Visual Feedback v. Non-Visual Feedback
Mass (lbs.)
450
400
350
300
250
200
150
Non-Visual FB
Visual FB


1RM: Visual Feedback v. Non-Visual Feedback
Mass (lbs.)
600
500
400
300
200
100
0
0
2
4
6
8
10
Subject
Non-Visual FB Max
Visual FB Max
Linear (Non-Visual FB Max)
Linear (Visual FB Max)



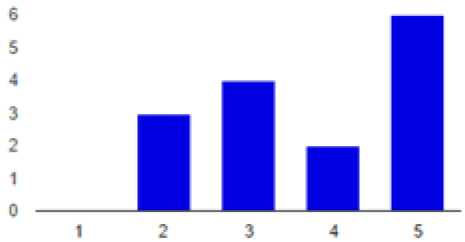
Mean 1RM as BW Percentage: Visual Feedback v. Non-Visual Feedback
% Body Weight
240
220
200
180
160
140
120
100
Non-Visual FB
Visual FB



1RM as BW Percentage: Visual Feedback v. Non-Visual Feedback
% Body Weight
300
250
200
150
100
50
0
0
2
4
6
8
10
Subject
Non-Visual FB
Visual FB
Linear (Non-Visual FB)
Linear (Visual FB)

Graph A.

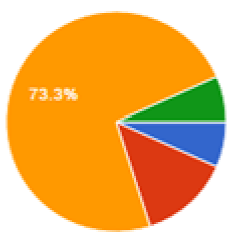
How comfortable were you performing a 1RM deadlift attempt prior to this study?



Not comfortable at all: 1	**0**	0%
2	**3**	20%
3	**4**	26.7%
4	**2**	13.3%
Very comfortable: 5	**6**	40%

Graph B

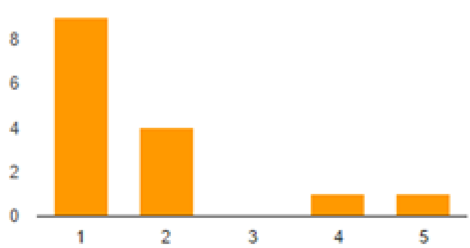
Were you consistent in using the visual stimulus?



I forgot to look at the screen	**1**	6.7%
I used it to find my starting position, but did not use it during the actual lift	**2**	13.3%
I used the screen the entire time	**11**	73.3%
Other	**1**	6.7%

Graph C

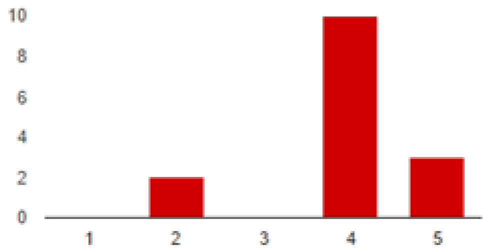
I feel that the visual aid of the realtime data was a hindrance to my ability to deadlift.



Strongly disagree: 1	**9**	60%
2	**4**	26.7%
3	**0**	0%
4	**1**	6.7%
Strongly agree: 5	**1**	6.7%

Graph D

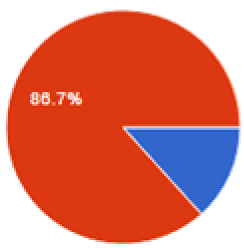
I feel that the realtime data helped me perform the deadlift.



Strongly Disagree:	1	0	0%
	2	2	13.3%
	3	0	0%
	4	10	66.7%
Strongly Agree:	5	3	20%

Graph E

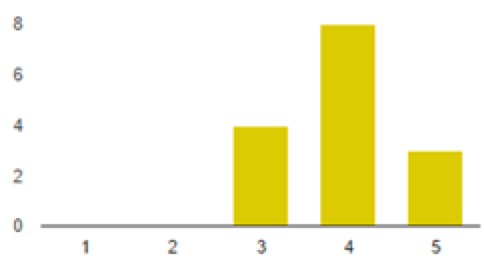
I prefered performing the lift:



With no feedback.	2	13.3%
With visual feedback.	13	86.7%

Graph F

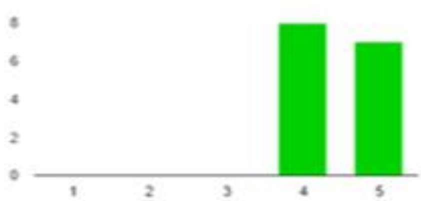
I feel safer performing the deadlift when visual feedback is provided.



Strongly disagree.:	1	0	0%
	2	0	0%
	3	4	26.7%
	4	8	53.3%
Strongly agree.:	5	3	20%

Graph G

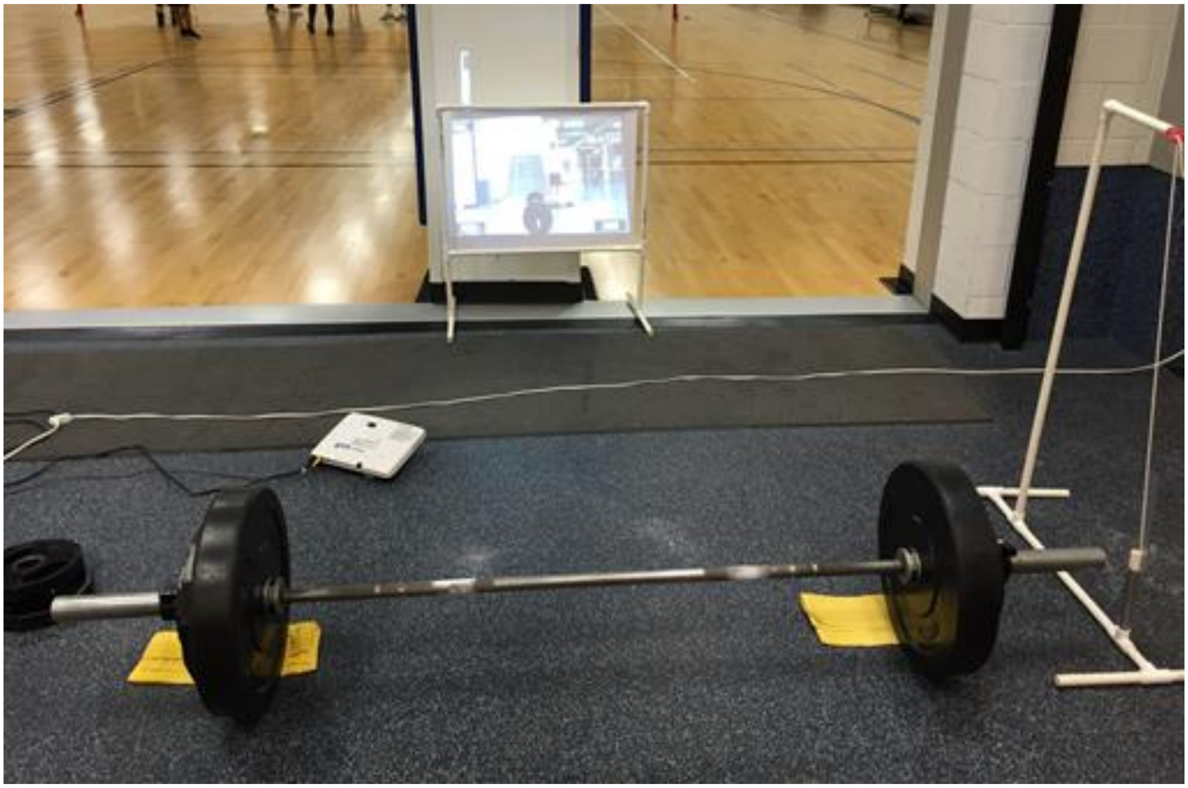
Even if you did not feel that the visual stimulus was beneficial to you personally, do do you think that the visual stimulus would have been helpful to you when you were first learning the deadlift?



Completely unhelpful:	1	0	0%
	2	0	0%
	3	0	0%
	4	8	53.3%
Incredibly helpful:	5	7	46.7%

Appendix C
Setup and Equipment:

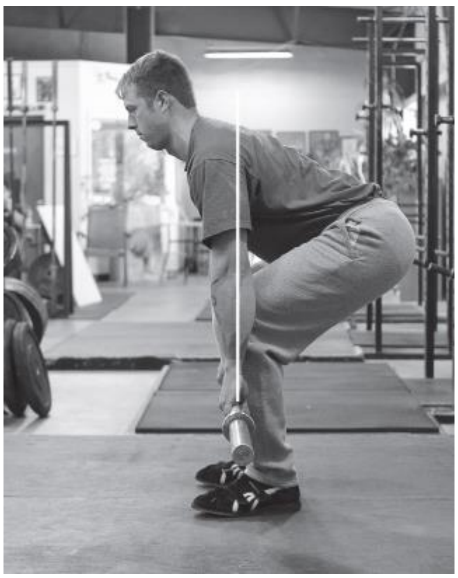
Equipment Used:
22x28 inch screen
Video Projector
Camcorder and Tripod
Angle approximation tool/reference line
Standard 45 lb. barbell



Handout provided to subjects:

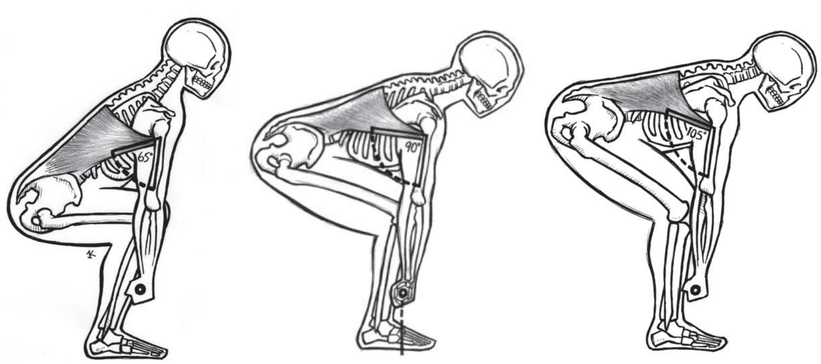
Deadlift Information and Guidelines

The correct position from which to pull will be one in which the scapulas, the bar, and the midfoot are aligned vertically. The back will be held rigid in its normal anatomical position, the elbows will be straight, and the feet will obviously be flat against the floor. This is the position in which the skeleton most effectively and most efficiently transfers force.



When the shoulder is in front of the bar and the back angle is stable in a pull, the angle of attachment between the lat and the humerus is about 90 degrees, since this is the angle at which the least muscular force is required to produce a rotation force that is equal and opposite to the weight. It is the angle at which these muscles can exert their tension on the humerus most efficiently and thus provide the maximum force transfer and stability during a pull from the floor in which the bar needs to stay over the mid-foot and as close to the hips as this stable "hang" will allow.

Stated more succinctly, the arms are not plumb in a deadlift because the lats do not attach to the arms at 90 degrees when the arms are plumb. The arms must slant back to achieve a position of stability as they hang from the shoulders. So the body must assume a position that allows the arms to be at 90 degrees to the lats and for the bar to be pulled in a straight vertical line off the floor. If the hips are too low, the lat attachment angle will be less than 90 degrees, and the hips will rise as the back angle adjusts to the stable position. If the hips are too high, the angle is greater than 90 degrees, and the lifter cannot as efficiently prevent the bar from continuing forward.



Take home points

Starting position:

Bar at midfoot

Chin tucked/neutral

Center of shoulder joint 7-10 degrees in front of the bar

Tension in the hamstring and back to create a flat and stable back

Execution of the movement:

Maintain a flat foot and press through the legs to lift the bar

Keep the arms straight

Hips should move synchronously towards the bar as the shoulders rise

No stalling allowed, bar must continue to move upward without resting and resetting on the thighs

Terminal Position:

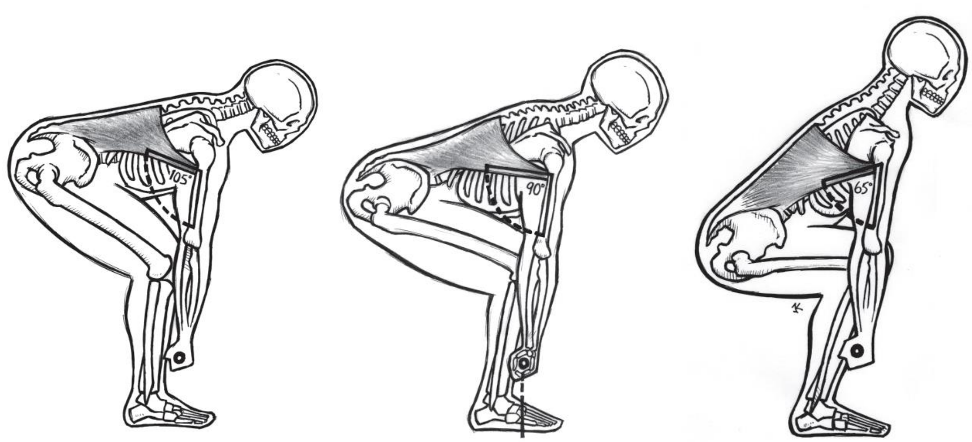
Knees and hips locked out

Must lower the bar to the ground under control

Quiz Provided to Subjects:

Please select the best answer for the following questions. An 80% must be obtained to continue.

1. Which of these starting positions is most correct? (The 2nd position is correct.)



2. The bar should start positioned:

A. *<u>At midfoot</u>* B. 2-3 inches in front of midfoot C Touching the shins

3. The shoulders should be positioned:

   A. *<u>7-10 degrees in front of the bar</u>*

   B. 7-10 degrees behind the bar

   C. Directly above the bar

4. The bar path should follow:

   A. A "C" shape

   B. A backward sloping line

   C. *<u>A very slight "S" shape, or nearly straight line</u>*

5. When considering the position of the head:

   A. The head should be thrown backwards

   B. The head should be flexed down forcefully and jaw tensed

   C. *<u>The head should be neutral with the chin slightly tucked</u>*

Survey Questions:

(1 indicates strong disagreement , 3 indicates neutrality, 5 indicates strong agreement)

1. How comfortable were you performing a 1RM deadlift attempt prior to this study? (0-5 scale)
2. Were you consistent in using the visual stimulus? (written response)
3. I feel that the visual aid of the realtime data was a hindrance to my ability to deadlift. (0-5 scale)
4. I feel that the realtime data helped me perform the deadlift. (0-5 scale)
5. I prefered performing the lift: (with visual feedback or without)
6. Even if you did not feel that the visual stimulus was beneficial to you personally, do you think that the visual stimulus would have been helpful to you when you were first learning the deadlift? (0-5 scale)
7. Please provide any other comments, concerns, etc. that you feel are relevant for us to know. (written response)

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