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The Effects of Stress on American Football Overhand Throw Accuracy

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Abstract

The American overhand football throw is a highly scrutinized position because of all the different kinds of stress both physical and psychological that are put onto those players. The current study sought to develop a formula using psycho-emotional and physical variables to predict the performance of an American overhand football throw under stressful/non-stress situations. Participants were tested on two days. The stress situation is where tennis balls were thrown, and the subject did not know where they were going to throw. The non-stressed was a 3 step drop without knowing what target they were throwing at and these conditions were covered each day. The first day, the 12 participants completed the first questionnaire, measuring both physical and psychological stress, the first set of 15 throws, and the second questionnaire to measure the same variables. For the next set of 15 throws on that day, the opposite condition was used. The second day, the sequence repeated for questionnaires and for the throws with the stress and non-stressed throws completed in the opposite order. Variables assessing psychological stress and arm motion were used to develop throwing models in stress and non-stress conditions. The developed models were able to predict performance at all throwing distances when using a regression analysis of the long, medium, and short throws with stress and non-stress. These models were cross-validated by a paired t-test and correlation. Conclusion: The throws studied we were able to predict ability to hit a target under both stress and non-stress situations. Different variables were influential each in condition, but Borg scale was the most common in the study. These models need to be tested again with other throws of similar distances to see if the models continue to be accepted.

Keywords: Front-swing, Back-swing, American overhand football throw, Stress, Non-stress, Questionnaires, Regression

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Chapter I: Introduction

In 2013, in an article for SBNation, Danny Kelly (2013) wrote, “quarterback was probably one of the most difficult positions to play in all of sports” (para. 1). He supported his claim by citing the myriad of skills necessary for the position: “excellent vision, defense recognition, athleticism, a strong arm, accuracy, and touch” (para. 2). However, he noted, those skills are just the beginning as quarterbacks must be able to decipher field organization and complete a throw within seconds, while simultaneously avoiding the defense. The component of stress plays a role in the success of a quarterback in a football game. The level of stress that is administered to a quarterback and the effect that will have on their performance is currently being researched. However, some think that certain levels of stress during training may improve performance in game situations (Jones, Hardy 1990 and Moore, Young, Freeman, and Sarkar 2017 and Oudejans 2009). In short, quarterback is a difficult position due to the complexity of a successful American football overhand throw and the stress under which it is completed.

Stephon and Khorbotly (2012) designed an application-driven target tracking system to improve the performance of a robotic football team; specifically, the researchers wanted to improve the throwing accuracy of the robotic quarterback and the catching odds of the robotic receiver. Light-emitting diode (LED) tracking allowed the quarterback to find and connect with the receiver. At 5 yards, the robots completed 100% of their passes. However, when the researchers moved the robots up to 6.67 yards, the robots were successful only 80% of the time.

Stephon and Khorbotly’s (2012) findings illuminate the difficulty of the quarterback’s task of connecting with the receiver. The assignment becomes even more difficult for professional players who need to throw beyond five yards. In fact, in the NFL during the 2017 season, the shortest average intended yards on a throw was 6.6 yards (https://nextgenstats.nfl.com/stats/passing#yards, 2017).

What factors account for the drop-in completion percentage? In a study involving 40 flag football players, Allain (2007) found situation-specific anxiety, as measured by heart rate, to be significantly correlated with the number of interceptions thrown by the athletes and negatively correlated with the percentage of games won. What causes that anxiety? Is it the task? The athlete's current affective state? The stress of the task? The length of the throw?

Quarterback is one of the most scrutinized positions in all of sports; they can heavily impact weather their team wins or loses a game, adding even more pressure on the individual for each play (Mark, 2013). Finding out which quarterbacks handle stress the best will allow us a greater ability to determine which quarterbacks are going to succeed and which ones will not.

Stress is also an important aspect of the American overhand football throw. Surveys assessing stress have been used to subjectively determine the stress level of each participant either before or after different events. Widely accepted measures of stress include the following: PANAS (Watson et al., 1988) is broken into two different categories of a positive and negative aspect; Rock climbing anxiety inventory, which is from a questionnaire created by Llewellyn, Sanchez, Ashghar, and Jones, in 2008. It is broken into positive and negative aspects of psychological and physical factors. The Borg Scale (Borg, 1982) of perceived exertion indicates if one condition is perceived to be more strenuous than another; the last questionnaire was a modified version of the NASA Task Load Index (Hart, 2006).

With all these questionnaires we can determine on a scale what variables have a stronger correlation to throwing performance. Following on the suggestion of Mark (2013), influencing variables likely include anxiety, perception of exertion, positive and negative psychological aspects, and a perception of what the task involves. It is likely that varying types of throwing situations have different variables that play a greater significance in determining a participant's ability to strike a target. Therefore, correlation and regression analysis can be used to determine the importance of the different variables on throwing performance. Thus, the current study sought to determine the relationship stress has on various psycho-emotional and physical variables to throwing performance at different distances.

Methods

Participants were selected through purposeful sampling (Merriam, 2009). Purposeful sampling was most appropriate for this research as the study design required participants with overhand throwing experience. Twelve male participants responded to requests for volunteers made in exercise science and athletic training courses at the university and in a local gym. The participants had a mean age of 26.9 years (*SD* = 6.4 years), mean height of 1.81 meters (*SD* = 0.05 m), and mean weight of 100.6 kilograms (*SD* = 21.2 kg). All participants had experience with overhand throwing techniques in either baseball (*M* = 5.56 years, *SD* = 4.5 years) and/or football (*M* = 5.45 years, *SD* = 2.46 years). Eleven of the twelve participants had football experience at some competitive level. All participants gave informed consent, in adherence with the study's Institutional Review Board (approval number HS14-584).

The intent of the task was to determine the accuracy with which participants could throw an American football at various target distances using an overhand throw. Accuracy was measured solely if the participants struck the target or not during both non-stressed and stressed situations. Participants could obtain a total of 20 points on each throw if the struck the target.

The setup for the experiment was the neutral box, estimated as the distance from the center to the tackle of the offensive line on the throwing arm side and five yards deep; with cones marking all the corners (see Figure 1) (National Football League, 2014b). The hardware that was used was an official size football, weighing between 410 – 460 g and inflated to 65.7-68.8 kPa. All three targets were free standing frames of 1.83 meters by 1.83 m (6ft by 6ft), see Figure 2. Tennis balls thrown at the participants were used to simulate pass rushers, which were to be avoided. Wrist acceleration data in the sagittal and transverse planes were recorded using the RehaWatch 4.1.9.0 (HASOMED GmbH, Magdeburg, Germany) at 500 Hz.

Three targets were located at different distances from the line of scrimmage, which is before the starting position for the initial drop back. The targets were always positioned on the dominant throwing side of the participant. In the current study, the location of the line of scrimmage was created from C and would go straight to the T location (C=Center and T=Tackle). All targets were positioned from location C in Figure 1. The first target was 18.3 m (20 yards) straight ahead. The second target was 9.1 m (10 yards) from location C and 9.1 m (10 yards) to the outside on the dominant side. The third target was 27.4 m (30 yards) from the location C and 9.1 m (10 yards) to the outside on the dominant side. Than the short and long targets where both turn 45 degrees towards the letter C as in Figure 1.

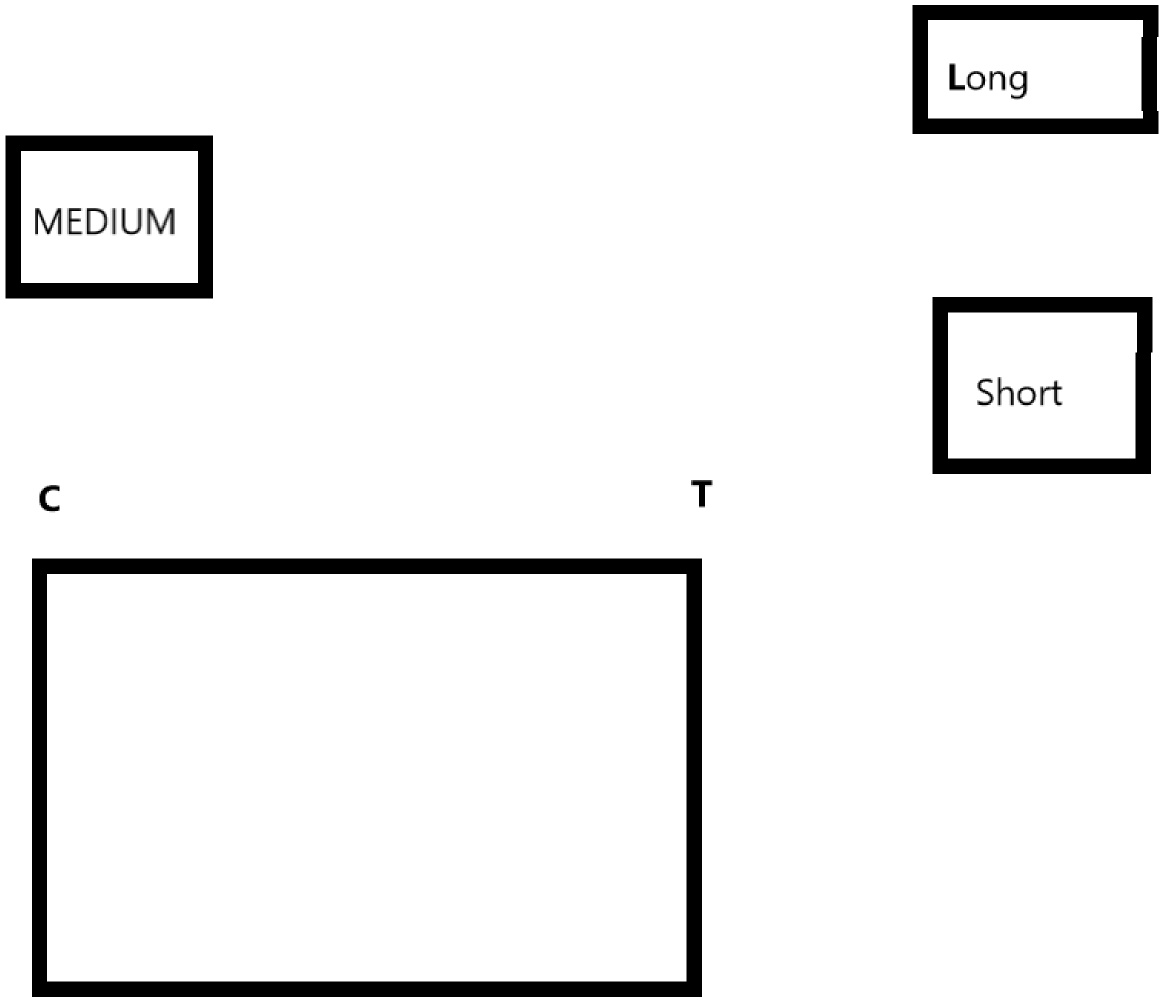

Figure 1 Square the subjects had to throw from to hit the targets. The letter C represents the center cone where the participants started. The letter T represents the tackle, the farthest to the dominant side the participant was able to move. Also illustrated are the three target locations relative to the starting from the C location. The first target was 18.3 m (20 yards) straight ahead. The second target was 9.1 m (10 yards) from location C and 9.1 m (10 yards) to the outside on the dominant side. The third target was 27.4 m (30 yards) from location C and 9.1 m (10 yards) to the outside on the dominant side. This target location and box size is not to scale.

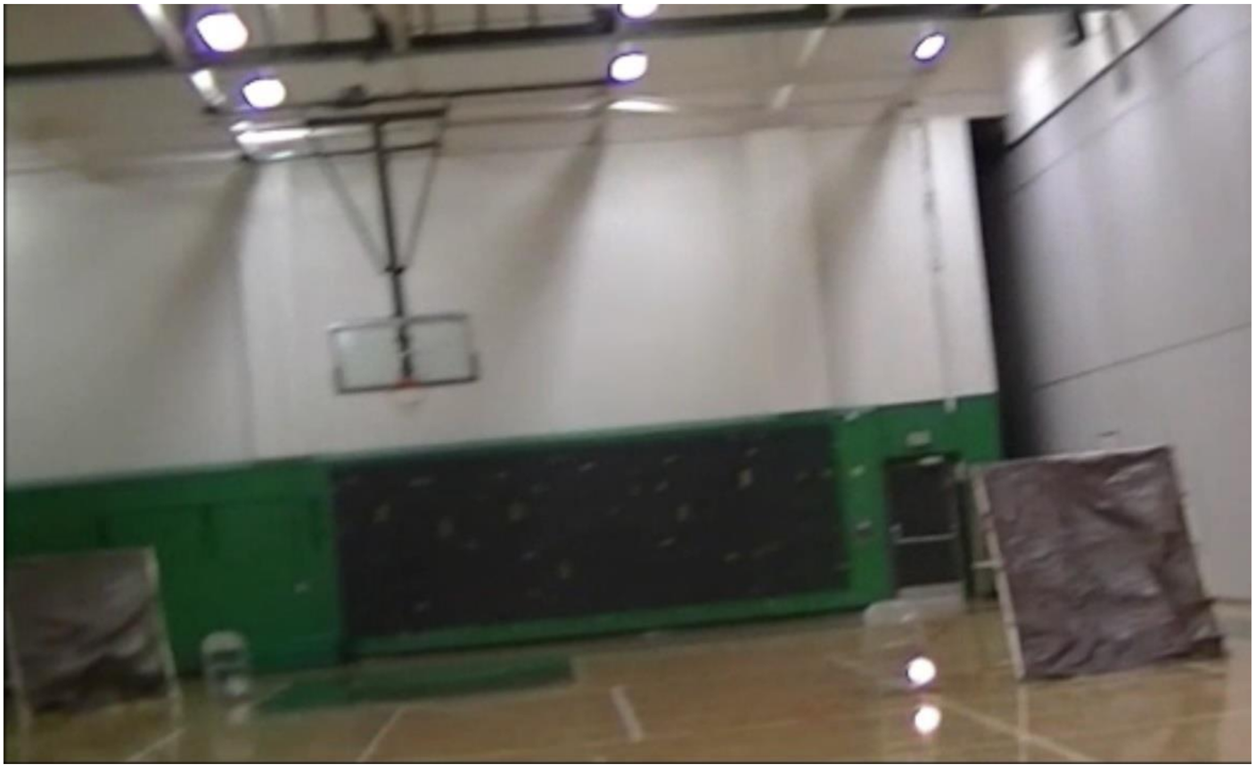

Figure 2 The targets were 1.83m by 1.83m standing at a 22.5-degree angle from the ground for support, as seen above.

Participants started off the first day of testing after all baseline information was collected by filling out the initial stress questionnaires (see Appendices A – D). Participants were asked if there were any previous injuries that would hinder their ability to perform on their day of testing. If so, they were excluded from participating in the experiment or asked to come back when the injury healed, if the study was still ongoing.

Four questionnaires were used to assess participants' stress: the Positive and Negative Aspect Scale (PANAS) (Watson, Clark, & Carey, 1988), the Throwing Anxiety Inventory was developed for the current study from another questionnaire (Llewellyn, Sanchez, Ashghar, and Jones, 2008), Borg Scale (Borg, 1982), and NASA Task Load Index (NASA-TLX) (Hart & Staveland, 1988). The questionnaires were given three times: prior to, in between throwing sequences, and after each round of throws.

The PANAS (Watson et al., 1988) was a self-report questionnaire that presents participants with a variety of keywords related to positive and negative affect, such as "jittery," "hostile," "enthusiastic," and "inspired." Participants rated the degree to which they feel each keyword using a continuum of one to five with one being "very slightly or not at all" and five being "extremely" (see Appendix A). Therefore, a high score meant a participant's positive or negative affect had more effect on him during an event. (See Appendix A) The PANAS was shown to be valid by Crawford and Henry (2004).

The Throwing Anxiety Inventory (THANIN) was developed for the current study and was modeled after the Climbing Self-Efficacy Scale (CSES) (Llewellyn, Sanchez, Ashghar, and Jones, 2008), currently this questionnaire is unvalidated. (See Appendix B)

The Borg scale was developed and validated many times since 1982 and is a scale of perceived exertion scale that is based on heart rate data (Borg, 1982). This self-report questionnaire requires users to rate their perception of physical exertion on a scale of six to 20 with six representing "no exertion" and 20 corresponding to the most exertion possible (see Appendix C). Fittingly, the easier the perceived exertion, the closer the score will be to six, and the harder the perceived exertion, the closer the score will be to 20. One such case of validation was by Ritchie (2012).

The last questionnaire was the NASA-Task Load Index (NASA-TLX) (Hart & Staveland, 1988), which measures the "cost" (Hart, 2006, p. 904) of accomplishing a task. The questionnaire consists of six categories of variables all self-assessed using a LOW/HIGH continuum (see Appendix D). The first category, MENTAL DEMAND, and the second, PHYSICAL DEMAND, assess the level at which the participant felt the task to be mentally and physically taxing, respectively. The third category, TEMPORAL DEMANDS, concerns the participant's perception of time pressure. The fourth, PERFORMANCE, asks the participant to rate the level of success he thought he accomplished. The fifth category, EFFORT, assesses the participant's mental and physical effort exerted toward accomplishing the task, and the final category, FRUSTRATION LEVEL, asks the participant to rate his level of insecurity, irritation, stress, and/or annoyance. Hart performed a meta-analysis about the different ways this questionnaire was used over the years since its creation (Hart, 2006).

While the NASA-TLX has been validated by Tubbs-Cooley, Mara, Carle, and Gurses in 2018, it was designed with a weighting scheme to compute the overall workload score. According to a meta-analysis by one of the NASA-TLX developers, "the most common modification made to

NASA-TLX has been to eliminate the weighting process all together [sic]" (Hart, 2006, p. 906). This was also the case for the current study.

The warm-up, which was the same for every trial, consisted of five minutes of low- to medium-exertion jogging followed by 30 seconds of right, left, and forward carioca (a side shuffle with a crossover step then changing sides and repeating) (Stine, 2012), high knee strides, high leg kicks, walking toe touches, standing trunk twists, forward and backward arm circles, overhead triceps stretch, and cross body reaches. Finally, participants performed easy throwing to keep their arms warm until data collection began.

Once ready to start the trial, an accelerometer was placed on the participants' throwing wrist and instructions were given. When the participant was ready, a coin was flipped to determine if stress or non-stress would occur first. They then drew one of four pieces of paper to determine the throwing sequence. Each of the four pieces of paper contained a number that was paired with a throwing sequence listed on another sheet. The sequences were blinded to the participants. The numbers were drawn by random selection without replacement.

Participants were told that they would be subjected to two different situations that they were to perform in a random order. Before they started the first trial, the participants had a lesson in how to perform a three-step drop and the target names (see Appendix H). In the non-stress situation, participants took two-drop steps, heard that target's name, took the final drop step/plant step, and then threw at the target. In the stress situation, during the final drop step (third step), the researcher threw tennis balls at them, which the participants had to avoid. The participants were instructed to avoid all three tennis balls. Once they avoided the last tennis ball they were required to place themselves in a position to make the throw in two steps or fewer. The tennis balls were thrown at the participant’s one at a time with the next ball thrown as soon as the preceding ball left the hand of the preceding thrower. To do this before each throw, study helpers came up with a random order to ensure the balls were coming fast, but such that there were no multiple balls reaching the subject at the same time. When the second tennis ball passed, the study helper with the sheet would say the name of the target the participant would have to throw at once he avoided the last ball.

Participants were given all the information as to how each condition would occur. Each day/stress situation involved the same number of throws, 15 each. Participants made a minimum of four throws to every target leaving three throws to any target. The reason they did not make five throws to each target was because participants would have a 50/50 chance at guessing the second to last throw and a 100 percent chance at guessing the last one. This would take the random nature out of each throw, which was different than in the real world. Once the first 15 throws were made, the participants repeated the questionnaires. Then, they were prepared to begin the alternative situation and asked if they had any questions about the testing. The participants would then complete the next 15 throws of a new sequence and complete the questionnaires a final time. At this time, the accelerometer was removed, data were saved, and participants were given a time to return.

In between each throw, thirty seconds of rest was given. During that time, the balls were collected, and confirmation of proper procedure was determined. In addition, if a participant had been hit with any of the tennis balls thrown by study volunteers, the points scored were subtracted from the total accumulated. No re-throws were allowed.

The second day was the same as the first day except the order of stress and non-stress was reversed. Thus, if a participant began with stress on the first day, he began with non-stress on the second. After the final test, participants were asked if they had any questions and then thanked for their time.

The backswing, front swing, and total arm movement times averaged for each throwing situation were added to the models. These times were calculated using the information gathered from the accelerometer. The initiation of movement was the first increase in gyro Z above baseline. Then we calculated the midpoint from the change in direction of gyro Z. The release point was the time point at maximum resultant acceleration. The movement time was the difference between time at point of release and initiation of movement. Backswing was the difference between time at point of release and the midpoint of the movement. Finally, the front swing was the difference between time at the midpoint and the point of release.

Variables of interest were all the stress variables from the questionnaires as well as the accelerometer data. Each participant was scored based each questionnaire's respective scoring guidelines and data were entered SPSS with the average scores for that round for short, medium and long throws. A correlation of the independent variables to the throwing score was performed, with significant correlations from the SPSS output displayed in Tables 2A - 7B. Correlations with the greatest significance to each throwing score. (I.e. long stress, short non-stress…) were selected to create the model, with the inclusion of the back and front swing accelerations in each case. A bootstrap regression analysis with cross-validation was performed with those variables for two purposes: (a) to give more data points, and (b) to validate the accuracy of the information (Jensen & Kline, 1994). Regression was performed in a stepwise manner 20 times; three participants' trials were randomly removed each time a regression was performed. This allowed us to find the averages of the mean, standard deviation, min, max, create the regression equations to find the expected score for that throw, and cross-validate the model. After the regression model was developed each equation was cross-validated with the holdout three subjects via paired T-test and correlation of the expected versus actual to see if the model would be accepted or rejected. Alpha of $p < 0.05$ was used for all significance testing. Because some of the 20 bootstrap models resulted in positive and others in negative correlations, the absolute value of the correlations was used to determine the Mean of the twenty correlations for each model.

Results

Table 1 illustrates the mean score and ±SD for the total of 6 throws that were made over the two different conditions. Tables 2 through 7 display a resampling cross-validation for the three different targets with and without stress. Multiple R values ranged from .46 to .98 with a Standard Error of Estimate (SEE) of 10.75 to 25.07. Out of the six different trials, the Borg scale was present in five of the equations; positive physical effect showed in four; positive psychological effect, mental and frustration showed in three; positive PANAS effect, negative PANAS effect, performance, and temporal each occurred in one equation. For the long throw without stress we had a predicted scoring mean of 30.94 with a SD of 42.30 (Table 2B). The long throw with stress found a predicted scoring mean of 24.45 with a SD of 13.73 (Table 3B). The medium score without stress had a predicted mean score of -176.83 with a SD of 318.43 (Table 4B). The medium score with stress had a predicted score of 29.61 that had a SD of 90.64 (Table 5B). The short throw without stress had a predicted mean of 52.91 that had a SD of 19.06 (Table 6B). Lastly, the short throw with stress had a mean prediction score of 45.24 with a SD of 22.24 (Table 7B). On Table 1 we see the means values of the throwing scores for stress and non-stress situations.

Of the six models created, none of the cross validations resulted in a significant difference between the actual and predicted throwing scores. Furthermore, all R-values except for medium throw with stress were equal to or above .70 indicating a strong linear relationship and the medium throw with stress came in with an R value of .67 providing us a moderate linear relationship. Table 2A displays a regression with a R value of .98, which was tied for the largest of the R values; while Table 2B shows a Paired T-value = .73 with a p = .46 between the predicted and actual throwing scores for the Paired T-test which means the T values are not significantly different and model can be accepted for the throwing scores. The paired t-test for long throw with stress in Table 3A we see an R value of .85 which would be the third largest R value score and a T value of 0.26 with a p value = to .54 in Table 3B, this shows we cannot reject the null because of that test. The medium throw with no stress used the Borg scale and Frustration variables, resulting in an R value of .67 (the lowest of all six R values found in the models); and with a t-test value of -1.76 and a p value = to .42 (see Table 4B), which indicates the model is valid. The medium throw with stress had correlations with the most variables Positive Psychological (THANIN), and Physical (NASA), Frustration (NASA), Performance (NASA), Mental (NASA), and Borg scale. For the medium throw under stress, Table 5A displays an R value of .98, which was tied for the largest and there was not a significant difference with a paired T value of -0.48 and a T probability value of .42 between the actual and predicted throwing score in Table 5B. In Table 6A the R value shows a value of .70 which was the second smallest R value found of the models. The short throw with no stress model produced a t-test score of -2.21 with a T probability of, 40 as shown in Table 6B, and the model is valid. Finally, for the short throw under stress, there was a correlation of the variables Frustration (NASA), Borg scale, Positive Physical Effect (THANIN), and Temporal (NASA) to throwing performance. The multiple R value of .78 was the fourth largest R value in Table 7A, while Table 7B shows a t-test value of -.88 with a T probability score of .48 meaning the model was valid. The correlations of each variable are as follows from strongest to weakest. The paired T-test correlation for the medium throw with stress is .77, which was our highest recorded. This was followed by medium throw without stress, then long throw non-stress, long throw with stress and short throw with stress had the same correlation. Finally, short throw with non-stress resulted in lowest paired T-test lowest correlation of theoretical to actual target score, .58.

Discussion

The current study examined factors that influence successful overhand American football throws; and which factors carry little weight. Of additional interest was whether variables were the same for different distance of each throw. These are important questions that have not been addressed in the literature to date. Correlation and regression were used to develop models to determine which variables had the greatest effect on throwing accuracy with and without stress. The variable that showed up the most was the Borg scale (Borg, 1982), the variable that examined perceived exertion. This variable showed up in five of the six conditions.

The Borg scale (which covers perceived exertion) and the positive aspects of both the physical and psychological of the THANIN questionnaire were correlated to the short throw with no stress throwing scores. The reason the THANIN variables showed up is because the short throw with no stress should be the throw that is the easiest (Llewellyn et al. 2008). With that, the participants would be the most comfortable in their skills to hit that target (Llewellyn et al. 2008 even though this pertains to rock climbing it is still a physical activity and as close as we can get). The perceived exertion showed up because it is a measure that the participant is doing work (Borg, 1982). The short throw with no stress standardized beta coefficients gave us the largest negative value -0.13 which was the Borg scale. Based on the negative value of the Borg scale we will see that as the perceived exertion increases the score they are able to achieve will decrease.

The most important standardized beta for each throw is as follows: the long throw with no stress Borg at -1.25; the long throw with stress is mental (NASA) at 1.15; the medium throw with no stress is Borg at -0.42; the medium throw with stress is positive physical effect (THANIN) at 2.33; the short throw with no stress was positive psychological effect (THANIN) at 0.55; and finally the short throw with stress was positive physical effect (THANIN) at 0.47. These four variables were the most influential in predicting the success or failure of a given throw.

The next model was the short throw with stress. Borg scale occurs even though the short throw stress exertion is still applied by having to maneuver around the tennis balls (Borg, 1982). Temporally (NASA), the participant's measure of time shows up for the first time. Since the participant was dodging tennis balls and then had to throw quickly to a short target this may be the cause of additional time issues for the participant (Hart, 2006). Even though the long target is the furthest away, which should mean more movement time, the participants did not express the temporal variable. The standardized beta coefficients with the largest negative value was temporal at -0.31 which means the subject felt they did not have enough time to make the throw. The largest positive standardized beta was positive physical effect at 0.47, which points to a participant feeling physically up to the task of being able to better make the throw (Llewellyn et al. 2008).

With the medium throw under stress we see six independent variables arise. Borg scale (partly because of the stress of the tennis balls), THANIN Positive Psychological (possibly because the throw is straight ahead and the subject believing it to be an easier throw) and Physical (not a very long throw). The medium and short throws all have the Borg variable that occurs, and it doesn't matter if it is stress or non-stress situations. Meaning all the throws are registering a certain level of exertion regardless of the stimulus. For the Medium throw with no stress and then the medium and short throw with stress frustration occurs. Meaning that something about the throws causes an increase level of frustration. A possible cause might be the location of the target (Hart, 2006). The medium target is straight ahead which when missed could increase a person's level of frustration. Then with the stressed short throw since they scored lower than the non-stress short throw which had the highest score. This could be the reason that frustration showed up during the stress version rather than the non-stress version. The stress was shown because of the Borg scale being correlated. Participants also needed to be in a positive physical and psychological anxiety state to have positive results as seen with the THANIN questionnaire. The other variables all came from the NASA Task Load Index and were mental, performance and frustration. These are all magnitudes that estimate the person's perception of workload right after an event (Hart, 2006). The medium throw under stress has the target lined up right in front of the participant, which could be giving the participant an anticipation of high performance in the NASA task load index. Since it is straight ahead of where they started the three-step drop; if a negative outcome occurs, it could result in great Frustration as assessed by the NASA task load index (Hart, 2006). The medium throw under stress possessed the largest negative standardized beta coefficient, the performance variable from the NASA task load index, at -3.42. The highest positive standardized beta was Positive Physical Effect from THANIN meaning that participants with strong feelings towards physical performance scored higher (Llewellyn et al. 2008).

The medium throw with no stress had Borg scale as its first variable, indicating that the subject felt these throws caused an increase in perceived exertion, much like it did for the other throws. The next variable was Frustration from the NASA task load index, which likely indicated the magnitude of how the participant feels when a negative outcome occurred (Hart, 2006). The standardized beta coefficients were all negative for this throw. The largest negative value came from Borg scale at -0.15, indicating the higher the perceived exertion, the lower the score. The closest to positive we came was frustration at -0.12; meaning if frustration got too high it would lead to lower overall scores (Hart, 2006).

The long throw with stress is unique because it is the only throw that perceived exertion did not show up in. The variables that did occur were Mental from the NASA task load index and Negative PANAS effect. Mental from the NASA task load index occurred as it did for the medium throw under stress. Where Negative PANAS occurred, it is likely the subject was responding to a negative mood state following the throws that were attempted for the long throw with stress (Watson et al., 1988). This model gave us standardized beta coefficients that only had positive values. The lowest was negative effect PANAS at 0.28, which could indicate that having negative feelings during this throw does not worsen the score, but these negative feelings from the PANAS questionnaire do not give a negative scoring based on the positive standardized beta achieved. The largest positive standardized beta for this throw was mental at 1.15; meaning the more mentally challenging the experience was, the greater the scoring outcome.

The long throw without stress shows variables Borg scale, Mental (NASA), Positive Psychological and Physical Effect (THANIN) that have all shown up in other throws and are showing up again for similar reasons as stated before. The new variable is the Positive effect PANAS, the opposite variable of the long throw with stress, meaning that the mood of the participants must have been higher when throwing to the long target without stress. The standardized beta coefficients give us the largest negative value of -1.25 for the Borg scale, which indicates the higher the perceived exertions the lower the subjects scored. The greatest positive value came from the positive PANAS effect at 1.82, which might indicate that being able to have positive feelings regarding a throw resulted in a greater scoring outcome (Watson et al., 1988).

The scores show the long throw with stress scored higher on average (m = 7.34 ±SD 4.21) then the long throw without stress (m = 6.92 ±SD 6.24). The medium throw without stress (m = 14.05 ±SD 5.86) and the short throw without stress (m = 16.73 ±SD 5.54), both of those scores were higher than their counterparts' medium throw with stress (m = 11.61 ±SD 4.99) and short throw with stress (m = 14.54 ±SD 4.17). This can be seen in all the throws without stress that they show a larger SD than their stressed counterparts. This should be investigated further because there may be further issues with consistency of the throws under the different stress stimulus.

The Borg scale is the only variable that shows up in all the non-stress throws. When comparing them as individual throws the medium throw has nothing else in common with the other two. However, the short throw and long throw have positive psychological and physical effects that show up in each. While the positive psychological effect for the long throw gives a negative standardized beta coefficient whereas the short throw for the same variable gives us a positive one. For the positive physical effect, they are both positive standardized beta coefficients. Even though the throw is longer it seems the long and short throws with no stress have similar physical stressor demands; where the long throw has a negative impact on the psychological aspect of the throw. One reason for this is the lower performance scores they achieved on those throws compared to the short throws.

The throws with stress had a different part in common than their non-stress counterpart. None had a variable that showed up in all three throws. However, the long throw and medium throws both had the mental variable occur. For the long throw it was positive, and the medium throw it was negative. With that even though they scored higher on the medium throws it seems that the long throws gave the subjects a higher mental feeling. Furthermore, the long throw has nothing in common with that of the short throw. For the medium throw and short throw, they have two in common; those are the Borg scale and Frustration. For the Borg scale the medium throw gave us a positive number where the short throw gave us a number almost at zero but still negative. Even though the throw was shorter, the perceived exertion must have seemed heightened because of the stress. Then for the frustration we got a positive score for the medium throw and a negative score for the short throw.

All throws when comparing them to their counterparts had two variables in common. Mental showed up in both as positive, the subjects must have had a positive mental experience after the throws. However, both throws correlated with the PANAS questionnaire and this is the only time the PANAS questionnaire shows up in any of the throws. The long throw without stress did with positive effect PANAS and the long throw with stress did with negative effect PANAS. They were both still positive, but the throwers under stress must have had more negative experience with the throws under stress than they did for the throws without stress.

For the medium throws they had both Borg and frustration that were found in each. For the medium throw without stress Borg had a negative value and for the throw with stress it had a positive value. One could show that the medium throw exertion had a greater affect during the non-stress throws than the stress throws. For frustration the medium throw without stress again had a negative value; while the throw with stress had a positive value. The subjects could still perform during the throw with stress and be frustrated where that was not the case for the throws without stress (Raôul et al. 2009).

The short throws both had Borg and positive physical effect occur. For both throws the positive physical effect was a positive standardized beta coefficient. However, in the throw without stress it was lower than that of the throw with stress. Meaning it gave a more positive result to that of the throw with stress. The Borg scale showed up as a negative standardized beta coefficient in both cases, however the long throw with stress was Borg value was very close to zero, where the value for the throw without stress was much larger. In Table 1 we notice that between the non-stress and stress models, which only once a stress throw had a higher score than that of the non-stress and that was during the long throw. If one continues to look at Table 1 they will also notice that for the stress throws the drops in scores from short to medium and medium to long seem to have a logical flow to them. However, during the non-stress scores we see a logical drop from short to medium but when we look at the drop from medium to long, that drop is much greater. This could be because the long throws with stress allow the participants to react with less constraints in the throwing motion.

Application of the models may allow coaches to better hone in on proper psychological training aspects to better assist their quarterbacks. For instance, for the three steps drop and throw with no stress, to the long, medium and short throws, the Borg scale showed up in each one and for each one gave us a negative value with the level of perceived exertion and the score they obtained. Whereas for the throws with stress, in the long throw Borg show did not show up, the medium throw had a large positive value, and the short throw had a standardized beta coefficient value of -0.05 which is a very low value compared to the other values for the non-stress situations. Using this information coaches may increase the pressure during practice and go back to those moments and use certain variables that are important for each throw to get the quarterback to start playing better (Oudejans 2009). Furthermore, the model may be able to begin the conversation on predicting a quarterback’s ability to connect on certain passes before they are even attempted in a game, which will allow a coach to better game plan around the throws his quarterback can and cannot make.

A limitation of the current investigation was the number of subjects that were able to complete the entire study. The time commitment to have people come back for two different days for an hour each was an unforeseen problem. Another was that these are just three specific throws of many that could be attempted in any given game. The subjects were not all true quarterbacks, which if they were trained differently could cause different results. With non-significant correlations because of the low number of participants in the study, however, there were no mean differences between the predicted and actual scores in the cross-validation t-tests.

Another limitation was the clinical nature of the setting in which the throws were performed, as it was devoid of the typical American football situation; in which the thrower was surrounded by other players, coaches, spectators, and much fanfare. The targets were not moving and the windows the participants had to throw through did not change. As we chose to not bring accuracy in as a main function, the targets used were graded only on if participants hit the target or not. They did not have a scale system for passes that are determined ideal for a route.

The variables we elected to record and examine were only those from the stress surveys and data from the accelerometers. As an initial study we focused on stress before moving to additional topics. The subjects were just asked to hit in any location on the target with no additional points for where or how they hit the target. Another possible topic of interest not studied in this paper, was that multiple subjects noted to the lead investigator that they felt “freer” during the stress events than they did during the non-stress situation even though their scores were less during the stress event. Working with people that played football, but maybe did not play the quarterback position may result in those subjects being better able to handle stress situations because they will not have to worry about the physical aspects and have a sense of what is about to happen having been in similar situations. Nevertheless, the current research is a starting point to examine the effects of stress on throwing performance in American Football.

Declaration of interest statement

The authors received no compensation for the results in this paper or to produce any findings.

Table 1 Throwing scores Means and ±SD used to create correlations

	Mean	SD
Long throw non-stress	6.92	6.24
Long throw stress	7.34	4.21
Medium throw non-stress	14.05	5.86
Medium throw stress	11.61	4.99
Short throw non-stress	16.73	5.54
Short throw stress	14.54	4.17

Table 2A Mean and ±SD of 20 bootstrapped equations for long throws no stress with a 3-step drop (n=9); throwing distance 27.4m forward and 9.1 yards towards dominant side.

Regression					
	Mean	SD	Min	Max	
R	0.98	0.02	0.94	1.00	
Multiple R	0.95	0.03	0.88	1.00	
SEE	10.75	5.00	0.95	21.05	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	112.16	130.05	-10.07	546.76	
Front Swing	-13.88	67.51	-172.40	164.12	-0.49
Back Swing	-0.14	26.81	-49.65	39.26	0.12
Borg Scale	-2.63	4.42	-17.47	3.15	-0.81
Positive Psychological Effect	-9.60	15.83	-73.97	3.85	0.75
Positive Physical Effect	3.01	5.99	-5.88	5.50	0.71
Mental	9.91	39.33	-81.36	9.86	-0.65
Positive effect PANAS	15.12	69.28	-115.50	54.83	0.58
Standardized Beta Coefficients					
Front Swing	-0.16	0.97	-2.02	2.68	
Back Swing	0.04	0.48	-0.78	0.82	
Borg Scale	-1.25	2.14	-8.66	1.62	
Positive Psychological Effect	-0.86	1.26	-5.86	0.44	
Positive Physical Effect	0.60	1.08	-1.07	4.58	
Mental	0.69	2.30	-4.66	4.81	
Positive effect PANAS	1.82	6.47	-5.93	25.49	

Regression SEE = Standard error of estimate. SD = Standard deviation.

Table 2B Cross-validation by paired T-Test for the long throw with no-stress; and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Long No Stress Actual	27.67	27.39	
Long No Stress Predicted	30.94	42.30	
T Value	0.73	4.37	0.46
Correlation	0.68	0.30	0.46

Standard Deviation = SD

Table 3A Mean and ±SD of 20 bootstrapped equations for long throws stress (evading 3 tennis balls) with a 3-step drop (n=9); throwing distance 27.4m forward and 9.1m towards dominant side.

Regression					
	Mean	SD	Min	Max	
R	0.85	0.04	0.76	0.90	
Multiple R	0.73	0.07	0.57	0.81	
SEE	13.87	1.21	11.44	16.59	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	-130.95	31.93	-204.87	-64.20	
Front Swing	-17.68	14.44	-67.70	4.11	-0.20
Back Swing	26.45	9.82	0.45	38.36	-0.01
Mental	8.78	1.43	6.44	13.01	0.62
Negative effect PANAS	3.54	1.82	0.53	6.57	-0.64
Standardized Beta Coefficients					
Front Swing	-0.26	0.20	-0.91	0.05	
Back Swing	0.50	0.19	0.01	0.73	
Mental	1.15	0.23	0.75	1.85	
Negative effect PANAS	0.28	0.16	0.04	0.61	

Regression SEE = Standard error of estimate. SD = Standard deviation.

Table 3B Cross-validation by paired T-Test for the long throw with stress and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Long Stress Actual	26.58	17.57	
Long Stress Predicted	24.45	13.73	
T Value	0.26	2.54	0.54
Correlation	0.64	0.33	0.50

SD = Standard Deviation

Table 4A Mean and ±SD of 20 bootstrapped equations for medium throws no stress with a 3-step drop (n=9); throwing distance 18.3m forward.

Regression					
	Mean	SD	Min	Max	
R	0.67	0.11	0.39	0.86	
Multiple R	0.46	0.14	0.15	0.74	
SEE	23.27	3.37	15.53	30.17	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	104.76	+67.42	-76.83	196.28	
Front Swing	-27.32	26.44	-60.91	44.08	-0.56
Back Swing	-19.81	24.52	-73.43	18.39	0.23
Borg Scale	-3.97	8.90	-24.17	10.00	-0.85
Frustration	-0.51	3.30	-9.41	6.36	-0.62
Standardized Beta Coefficients					
Front Swing	-0.42	0.34	-0.90	0.46	
Back Swing	-0.26	0.36	-0.93	0.46	
Borg Scale	-0.15	0.49	-1.01	0.84	
Frustration	-0.12	0.47	-1.40	0.57	

Regression SEE = Standard error of estimate. SD = Standard deviation.

Table 4B. Cross-validation by paired T-Test for the medium throw with no-stress and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Medium No Stress Actual	53.00	24.66	
Medium No Stress Predicted	-176.83	318.43	
T Value	-1.76	4.21	0.42
Correlation	0.69	0.32	0.43

SD = Standard Deviation

Table 5A Mean and ±SD of 20 bootstrapped equations for medium throws stress (evading 3 tennis balls) with a 3-step drop (n=9); throwing distance 18.3m forward.

Regression					
	Mean	SD	Min	Max	
R	0.98	0.05	0.84	1.00	
Multiple R	0.97	0.09	0.70	1.00	
SEE	25.07	9.63	14.77	33.86	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	-177.64	686.04	-2122.68	713.21	
Front Swing	-12.26	244.94	-621.95	547.23	-0.53
Back Swing	-78.02	122.94	-375.99	82.58	0.62
Borg Scale	+16.00	+23.63	-20.43	70.77	0.62
Mental	-3.23	+12.90	-24.82	24.39	0.58
Performance	-19.90	26.65	-84.17	11.95	0.63
Frustration	2.98	19.65	-29.50	49.76	-0.60
Positive Physical Effect	64.95	154.45	-150.44	383.69	-0.68
Positive Psychological Effect	23.53	155.51	-228.14	398.29	-0.64
Standardized Beta Coefficients					
Front Swing	0.18	3.01	-3.93	8.59	
Back Swing	-1.30	2.03	-5.91	1.59	
Borg Scale	1.64	2.53	-1.89	7.66	
Mental	-0.43	1.57	-3.98	3.01	
Performance	-3.42	5.45	-16.91	1.96	
Frustration	0.39	2.20	-2.72	6.14	
Positive Physical Effect	2.33	5.96	-6.37	13.81	
Positive Psychological Effect	1.22	6.95	-8.01	20.74	

Regression SEE = Standard error of estimate. SD = Standard deviation.

Table 5B Cross-validation by paired T-Test for the medium throw with stress and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Medium Stress Actual	50.83	23.03	
Medium Stress Predicted	29.61	90.64	
T Value	-0.48	1.66	0.42
Correlation	0.77	0.26	0.37

SD = Standard Deviation

Table 6A Mean and ±SD of 20 bootstrapped equations for short throws no stress with a 3-step drop (n=9); throwing distance 9.1m forward and 9.1m towards dominant side.

Regression					
	Mean	SD	Min	Max	
R	0.70	0.13	0.50	0.93	
Multiple R	0.51	0.18	0.25	0.86	
SEE	22.87	6.18	11.30	31.43	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	51.20	58.67	-114.04	127.72	
Front Swing	-16.92	26.69	-87.29	26.86	-0.14
Back Swing	-22.24	18.86	-49.93	37.85	+0.11
Borg Scale	-1.32	5.52	-11.30	10.90	-0.60
Positive Psychological effect	7.51	38.49	-66.70	108.58	0.67
Positive Physical effect	2.40	44.34	-106.44	87.67	0.59
Standardized Beta Coefficients					
Front Swing	-0.31	0.49	-1.45	0.42	
Back Swing	-0.47	0.43	-1.03	1.01	
Borg Scale	-0.13	0.55	-1.09	1.27	
Positive Psychological effect	0.55	2.32	-2.54	6.62	
Positive Physical effect	0.04	2.08	-5.43	2.75	

Regression SEE = Standard error of estimate. SD = Standard deviation.

Table 6B Cross-validation by paired T-Test for the Short throw with no-stress and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Short No Stress Actual	62.00	23.39	
Short No Stress Predicted	52.91	19.06	
T Value	-2.21	4.68	0.40
Correlation	0.58	0.34	0.55

SD = Standard Deviation

Table 7A Mean and ±SD of 20 bootstrapped equations for Short Throws Stress (evading 3 tennis balls) with a 3-step drop (n=9); throwing distance 9.1m forward and 9.1m towards dominant side.

Regression					
	Mean	SD	Min	Max	
R	0.78	0.11	0.58	0.98	
Multiple R	0.62	0.18	0.33	0.96	
SEE	20.52	6.07	5.62	28.61	
Unstandardized Beta Coefficients	Mean	SD	Min	Max	Correlation
Constant	55.13	284.28	-977.21	357.05	
Front Swing	-13.66	26.67	-58.60	40.78	-0.5
Back Swing	-11.89	14.69	-37.06	23.57	0.07
Borg Scale	-0.21	9.47	-11.06	33.85	0.62
Temporal	-1.27	4.64	-5.44	15.12	-0.62
Frustration	-1.75	6.70	-10.06	19.68	0.64
Positive Physical Effect	10.41	17.92	-9.35	52.96	-0.72
Standardized Beta Coefficients					
Front Swing	-0.28	0.49	-1.30	0.58	
Back Swing	-0.27	0.31	-0.85	0.47	
Borg Scale	-0.05	0.96	-1.24	3.28	
Temporal	-0.31	0.72	-1.14	2.07	
Frustration	-0.21	0.83	-1.22	2.49	
Positive Physical Effect	0.47	0.88	-0.61	3.00	

Regression SEE = Standard error of estimate. SD = Standard deviation

Table 7B Cross-validation by paired T-Test for the Short throw with stress and correlation of the actual and predicted of the 20 bootstrapped regression models.

Paired T-Test	Mean	SD	Probability
Short Stress Actual	58.58	19.03	
Short Stress Predicted	45.24	22.24	
T Value	-0.88	2.19	0.48
Correlation	0.64	0.31	0.49

SD = Standard Deviation

Chapter II: Literature Review

Much is known about American football, and much has been studied with regards to the sport. Current research on American football has examined injuries to the cervical spine, in children, and in Finnish players; kickers; brain injuries, hypoconnectivity, and hyperfrontality in retired players; epidemiology of neurodegeneration; traumatic subscapular tendon tear in adolescent players; kidney injuries; amputation as a result of digital dislocation; posterior sternoclavicular dislocation; muscle cramps; effort thrombosis; and concussions and prediction of injury (Anderson et al., 2009; Apuzzo, 2013; Brophy et al., 2008; Brophy, Wright, Powell, & Matava, 2010; Gibson, Gurley, & Trenhaile, 2013; Gorard, 1990; Harrison, 2014; Karpakka, 1993; Lehman, 2013; Marker & Klareskov, 1996; Murrell, Maddali, Rodeo, Barnes, & Warren, 1999; Podberesky, Unsell, & Anton, 2009; Ryan, Fullmer, & Murray; 2011). In addition, heat problems, extreme heat hazards for football players, and football uniform heat stress, and hyperthermic exhaustion have been investigated (Armstrong et al., 2010; Grundstein, Cooper, Ferrara, & Knox, 2014; Swartz, Mihalik, Decoster, & Hernandez, 2012). Along with miscellaneous articles on history, goal-line technology, emergency helmet removal techniques, drag force on the football, physiological aspects, effects of height in high school players, helmet use, American Indians and football, overweight and obesity in youth participants and safest sprint starting position have also been studied (Altschuler, 2013; Campbell, Guidry, Lopez, Estis, & Bellar 2012; Bergfeld, 1999; Bonnechere, Beyer, Rooze, & Sint, 2014; Dewey, 1930; Malina et al., 2007; Pincivero & Bompa, 1997; Swartz et al., 2012; Watts & Moore, 2003). These are some but not all the studies available on American football. However, what is evident is a glaring hole in research on the psychological and physical variables that influence throwing success under stress and non-stress situations.

This review will begin with background information on the forward overhand pass, requirements of the quarterback position, and what is done when a forward pass is thrown. This will be followed by aspects of stress placed on the quarterback and finally various means to measure and assess the presence of stress.

The Forward Overhand Pass

The American football overhand throw is a movement that encompasses the entire body, working in unison to achieve the proper sequence. The biomechanics happen in all three planes (Kelly, Backus, Warren, & Williams, 2002) in three phases. In the initial phase of throwing, the quarterback takes the ball from the center and steps away from the line of scrimmage first with his dominant foot thus pointing his non-dominant shoulder towards the line of scrimmage as he completes a crossover step away from the scrimmage line. The ball starts at chest level between both hands. The dominant foot is then planted when the desired distance of the drop back is reached. Throwing starts when the quarterback decides on a location for the ball and starts to move the non-dominant leg toward the location he wants to throw. Depending on the ability of the quarterback, along with some body structural factors, the step forward may or may not happen at the same time as the hands separating from the ball (Heppe, 1992).

The second phase is the loading phase. With the forward movement of the dominate arm, the dominant hip will abduct, beginning the process of rotation of the pelvis. As movement of the dominant arm begins to result in a small angle of internal rotation, the dominant shoulder is abducted, and the elbow joint is flexed. At the same time, the non-dominant foot is striding out towards the target. The arm should come to a 90-degree angle at the elbow with the palm of the hand up toward the sky, and the shoulder joints should have a 0-degree angle. They will now plant the non-dominant foot on the ground with the toes pointed at the target (Heppe, 1992).

Finally, during the unloading, or throwing, phase, the hips begin to rotate counterclockwise, which moves the upper body in a counterclockwise rotation around the planted, non-dominant foot. The elbow leads the arm movement with the hand and ball slightly lagging. Rotation continues around the planted non-dominant foot. As the hip rotation ends, the shoulder girdle continues its rotations as the thrower twists around the hips and activates the extension of the elbow joint, followed shortly after by the release of the ball. As the ball is released the wrist moves from supination to pronation, and the dominant arm is internally rotated (Heppe, 1992). However, the sequence may happen at different points if the throw type varies.

Complexity of the pass. Many coaches, exercise scientists, and kinesiologists have agreed that the American overhand football throw is "the most complex motor skill in all of sports" (Maddox, 2011, para. 2). Part of the complexity stems from the myriad of synchronous physical skills required of the quarterback, in addition to the biomechanics mentioned above. Maddox (2016) identifies those skills as the following: (a) proper throwing mechanics - extra movement will increase the time to release, along with effort it takes to throw the ball; (b) accuracy - essential in order to hit the quickly closing windows of opportunity that occur on throwing plays; (c) quick delivery - delivering the ball quickly is equally as important as accuracy because if the quarterback takes too long to pass, those windows he will be throwing into will close quickly and result in sacks or interceptions; (d) arm strength - however a strong arm alone is not sufficient, and (e) footwork - adept footwork is needed in order to avoid being hit along with getting in the proper position in order to use the arm strength addressed above and deliver the ball at the appropriate time to the receiver.. The throw must be a coordinated effort from the ground up.

The overhand throw is also complex because of a plethora of events happening on field that require the mental focus of the quarterback. The quarterback must know what the ten other players on offense are doing and in a matter of seconds, understand what eleven players on defense are doing. The offense must be set in one position before a play begins. While the defensive players can see where each offensive player was positioned, they are free to move wherever they want if they do not cross the line of scrimmage. If the quarterback is under center, he will take the snap from the center as he performs a one-, three-, and five- or seven-step drop into the pocket. If a quarterback is in the shotgun position, then he is already in the pocket and will just take one step, which is usually with the dominant foot. From the snap of the ball, the quarterback has about 2.51 seconds to get the ball out of his hand (Epstein, 2013). As the quarterback makes his drop, he reads his "keys" for a given play, which in most cases consist of the actions of the middle linebackers and the two safeties. These "keys" for a play give him even more information as to the type of defensive coverage he is facing. In addition, he usually has five different receiving options, or in American football jargon progressions, on each play (on each play a quarterback will have five options to throw the ball to. During practice the coach will tell the player here is where you look first, then second and so on until five. Those are the progressions and each play may have a different sequence.) Typically, a quarterback will only make it through one or two of these progressions because he must to throw the ball to the first person he deems feasibly open. Once he decides the direction of the ball, he must ascertain how to successfully get the ball to the target. The quarterback must throw the ball with the proper speed and height to avoid the defensive players. The margin for error becomes greater the farther the ball is thrown down field. A ball traveling 27.4 meters (30 yards) down field and is greater than four degrees off the axis/spiral, can end up as far as 1.5 meters away from the intended target (Fleming, 2010). While the quarterback analyzes all these different aspects of a given play, the defensive player is reacting to him and attempting to harass him into making a mistake. They attempt to force him into a fight or flight mechanical state (Reynolds, 2012) that could result in a greater chance of a mistake.

Consistency and Stress

A closed skill is a skill in which the situation under which it is performed stays relatively constant, such as a pitcher throwing a baseball to the catcher (Wang, et al., 2013). The mound, the distance from the pitcher's mound to the catcher, and the width of home plate remain the same throughout the entire game. The only things that change are the minimal and maximal height the ball can reach and still be considered a strike. Examples of closed skills include kicking a kickoff, diving from a platform, shooting a basketball free throw, and swimming laps in a pool. These are all activities where repetition is the key (Ericsson & Smith, 1991). An open skill is a skill in which the situation under which it is performed is always in flux. During the 2017 season, NFL quarterbacks threw, on average between 29.6 and 42.1 passes per game (https://www.teamrankings.com/nfl/stat/pass-attempts-per-game), and each throw was under unique conditions. Thus, the quarterback is performing an open skill (Ericsson & Smith, 1991). Glass and Singer (1972) studied the effects of controllable and uncontrollable stressors on participants' abilities to proofread by emitting a 108-decibel noise during the task. Half of the subjects were given instructions for terminating the noise while the other half had no such instructions, and thus, no control over the noise. The proofreaders with the perceived control reported less frustration and performed better on the task than did those in the no-control group (as cited in Cohen, 1980, p. 83).

Athletes are susceptible to similar types of uncontrollable stressors. Wilson, Peper, and Schmid (2006) reported an incident in which a visiting volleyball team "completely lost its composure" during a pivotal fifth match when the home team's spectators began "stamping their feet and clapping in unison whenever the away team was serving the ball" (para. 3). The visiting team lost the match.

Unpredictability and uncontrollable situations are frequent occurrences in football, as they involve many open skills. For example, as a play develops, the receivers could be stopped at the line, which could throw off the timing of the quarterback's throw, or the quarterback, because of pressure from the defense, might not be able to see a certain receiver and must move around the pocket to find space to throw. Moreover, the quarterback could be hit as he throws. These are just a few examples that could arise during the throwing portion of the play. So, how do these uncontrollable situations affect the quarterback's perception of his task? Further, how does he proceed with the next throw after experiencing such stress on a previous pass? Which variables affect his throwing success? Or what types of measurement tools can be used to assess any presence of stress?

Questionnaires

Affect. To answer these questions, previous research offers some avenues for exploration. PANAS was developed as a reliable, valid measure of positive and negative affect (Watson et al., 1988). Positive affect reflects a person's level of alertness and energy. High positive affect "is a state of high energy, full concentration, and pleasurable engagement" (p. 1063). Because the quarterback's task involves significant cognitive processing skills (Allain, 2007), high positive affect is most desirable for quarterbacks on the field. Negative affect is "a general dimension of subjective distress and unpleasable engagement that subsumes a variety of aversive mood states including anger, contempt, disgust, guilt, fear, and nervousness" (Watson et al., p. 1063). Hadd and Crocker (2007) used the PANAS in a study of adolescent Canadian swimmers. They found that "pre-event stress-related variables" (p. 152) persisted throughout events, resulting in post-event negative effects.

Self-Efficacy and Task. In a meta-analysis, Moritz, Feltz, Fahrbach, and Mack (2000) found a significant correlation between self-efficacy and sports performance. Self-efficacy in basic terms is "situationally specific self-confidence" (Feltz, 1988, as cited in Moritz et al., 2000, p. 280). For instance, Llewellyn et al. (2008) found that rock climbers with high levels of self-efficacy took additional risks and attempted more difficult climbs than did their counterparts with lower levels of self-efficacy. Therefore, the degree to which an athlete feels confidence in his performance is related to the perceived difficulty, or risk, of a task. Likewise, an athlete with high self-efficacy, with regards to the task, will expend greater efforts toward the task.

The Borg Scale (Borg, 1982) and the NASA-TLX (Hart & Staveland, 1988) have been shown to be valid and reliable measures of task-related variables, such as frustration level and amount of perceived exertion. Coupled with measures of self-efficacy and positive and negative affect, these task-related measures may contribute to determining the variables that influence the successful completion of the overhand football throw.

Summary

The American overhand football throw is an open chain skill where the quarterback has stress from not only worrying that the offensive players will move to the right spot at the right time; it is compounded by the added stress of the defensive players moving to a position unknown to the quarterback. With that understanding, the stress of the quarterback is important to understand because it will affect his performance. Some ways of assessing stress include the PANAS survey, Throwing Inventory Index, Borg Scales, and the NASA Task load index to find a stress level of each quarterback. With all of this we may start to outline what is needed to be an above average quarterback, despite the lack of research in this area.

Chapter III: Conclusion and Recommendations

The purpose of this paper was to see what variables were important in stress and non-stress situations to aide in a participant's ability to successfully strike a target. The first step is developing a model that indicates accurate results and shows what different factors are needed to address the various aspects of the American overhand football throw. The most commonly used variables were Borg Scale, positive physical effect, positive psychological effect, Mental, and Frustration. The American overhead football throw is an area that has had little research done on it. Great quarterback play is not just physical or psychological, but a mixture of both judging by the variables that show up in each of the different models as seen in Tables 2A to 7A. This illustrates why it is such a challenging process to determine the factors that are occurring.

When we had each subject fill out the different questionnaires the complete 53 variables that we ran correlations over reach day ballooned this number to up over 300 variables. Of those 300 plus variables only nine of them correlated into the different models developed and of those nine only five show up in multiple models. These five may be the building blocks for a future master model. The master model variables would include Borg scale, positive Physical effect (THANIN), Positive Psychological effect (THANIN), Mental (NASA), and Frustration (NASA). However, the biggest to consider is how other variables play a factor in the master model as well. Some of those could be cortisol levels (Sladek, Doane, Luecken, Eisenberg, 2016) and heart rate (Allain, 2007) to name a few examples. Hopefully if these are found to correlate well with our throws they will increase the accuracy of the models' ability to predict all throws.

Another key component is that a football throw needs a proper mixture of both physical and psychological traits. The picture is starting to form because of the five variables that show up in multiple stress and non-stress situations, based on the manner the participants answer the questionnaires. The Borg scale and positive physical effect (THANIN) occur in multiple models on stress and non-stress. These both address what a participant was thinking, and what was physically occurring during the given throw. Than on the psychological side of table we see Mental and Frustration both from (NASA) and positive psychological effect (THANIN). This means that a mixture of both physical and mental features is needed for a successful throw to take place.

Another observation is the change in scores that happens on the stress side of the models when comparing those scores to the scores that occur in the non-stress models. The reason this is so interesting is because during the study multiple participants told the researcher that they felt more comfortable and freer during the stress throws, which became less thinking and more reacting. We did not measure this but an observation by the lead researcher was that some of the subjects that could not even reach the long target when doing the non-stress situation, however were able to reach the long target when stressed.

Findings from the current study may provide the coach a chance to address those issues sooner instead of going unnoticed and becoming a habit that is harder to correct. For instance, on a short out route with stress, the temporal variables occurred. When a player is struggling with completing a short out, a coach would know this key factor and may address the point that his quarterback is struggling with, and the coach could advise him to slow down the throwing process. Whereas the long throw with stress has the NASA task load index variable mental occur. This indicates that throws might come from physiological stressor that this long throw with stress is mentally challenging for the quarterback to complete. Finally, during the medium throw with stress a variable that occurred was the frustration; by controlling this we may see an improvement in the throws. With all these variables at a coach's finger tips. They could address the same player differently for all different throw types.

If it is possible to develop a master model to help coaches give faster, more useful coaching cues during the fast pace of a football game, this could be useful in the applied aspect. All the models created for the different throws were correlated with only nine variables. If someone created a master model, then it would be much easier for a coach to address his quarterback and give him the proper feedback to begin the process of eliciting more productive throws at that distance. However, this procedure would have to be recreated for throws of other distances.

A more involved study would be to see if an athlete's throwing mechanics change while under stress. Such a study would require 3D motion analysis to breakdown the throwing motions and a larger team of people working together to score each participant's throws. This may show small breakdowns in mechanics that would go unnoticed in non-game situations.

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Appendix A

Positive and Negative Aspect Scale (PANAS) (Watson et al., 1988)

This PANAS consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now.

Use the following scale to record your answers.

1	2	3	4	5
Very slightly/not at all	A little	Moderately	Quite a bit	Extremely

_____ interested	_____ irritable
_____ distressed	_____ alert
_____ excited	_____ ashamed
_____ upset	_____ inspired
_____ strong	_____ nervous
_____ guilty	_____ determined
_____ scared	_____ attentive
_____ hostile	_____ jittery
_____ enthusiastic	_____ active
_____ proud	_____ afraid

Appendix B

Throwing Anxiety Inventory

Directions: A number of statements that throwers have used to describe their feelings before throwing are given below. Read each statement, then circle the appropriate number to the right of the statement to indicate ***how you feel right now.*** There are no right or wrong answers.

1 = Not at all 2 = A little 3 = Moderate 4 = Strongly 5 = Very Strongly

1. I feel jittery.	1	2	3	4	5
2. I feel ready to make the physical exertion required.	1	2	3	4	5
3. I feel my heart is beating rapidly.	1	2	3	4	5
4. I feel strong.	1	2	3	4	5
5. I'm confident about coming through under pressure.	1	2	3	4	5
6. I am nervous.	1	2	3	4	5
7. I feel physically ready for the throws.	1	2	3	4	5
8. I find it easy to concentrate.	1	2	3	4	5
9. I feel I may not throw as well as I should.	1	2	3	4	5
10. I have sweaty palms.	1	2	3	4	5
11. I feel physically tense.	1	2	3	4	5
12. Overall, I feel confident in my own ability to succeed.	1	2	3	4	5
13. I can picture all the throws.	1	2	3	4	5
14. I feel anxious.	1	2	3	4	5
15. I can mentally picture myself making the throws	1	2	3	4	5
16. I am concerned I will not be able to make the passes.	1	2	3	4	5

17. I’m confident I will be able to make the passes.	1	2	3	4	5
18. I worry about failing on different attempts.	1	2	3	4	5
19. I feel focused and ready to start.	1	2	3	4	5
20. Overall, I’m confident in my physical and mental ability.	1	2	3	4	5
21. I am concerned I will throw to the wrong target.	1	2	3	4	5
22. I worry about failing.	1	2	3	4	5
23. I’m not concerned with throwing to the wrong target.	1	2	3	4	5
24. I have an underlying sense of uneasiness .	1	2	3	4	5
25. Confident I have adequate skills to complete the task	1	2	3	4	5

Appendix C

Borg Scale: Rating of Perceived Exertion (Borg, 1982)

Circle the number that best describes how hard you felt you were just working.

6

7 very, very light

8

9 very light

10

11 fairly light

12

13 somewhat hard

14

15 hard

16

17 very hard

18

19 very, very hard

20

Appendix D

NASA-Task Load Index (Hart et al., 1988)

Mental – How much mental and perceptual activity was required?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Physical – How much physical activity was required?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Temporal – How much time pressure did you feel?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Performance – Circle the number that gives the best indication about how well you think that you performed (0 = very bad … 20 excellently).

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Effort – Circle the number that give the best indication about how hard you had to work to complete the task (0 = little effort … 20 extreme effort)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Frustration – Circle the number that gives the best indication about how you felt with regard to stress and tension (0 = unstressed … 20 = extremely stressed)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Appendix E

Non stress test Throws

Scoring sheet with the scores the participant gets for both hits and misses

20 points for a hit or 0 for a miss

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

Appendix F

Stress Test

Scoring sheet for the stress throws with the instructions on how to score the throws, then what to do if they are stuck by a tennis ball.

20 points for a hit or 0 for a miss and minus 5 points if they were struck by any balls and minus 5 points if they leave the designated area

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

Total score ____

Appendix G

Throwing Protocol

These were the sequence of the throws that each subject threw.

Sequence #1

Long

Medium

Long

Medium

Medium

Short

Medium

Short

Medium

Short

Medium

Short

Long

Medium

Long

Sequence #2

Medium

Short

Short

Long

Medium

Long

Medium

Short

Long

Long

Medium

Short

Long

Medium

Short

Sequence #3

Short

Short

Long

Short

Long

Medium

Short

Long

Medium

Short

Long

Short

Long

Short

Medium

Medium

Medium

Long

Sequence #4

Short

Long

Long

Medium

Medium

Short

Long

Long

Medium

Short

Short

Medium

Medium

Long

Long

Appendix H

Script for the throwing procedure

You will take the snap from a quarter squat position with arms extended at about a 45-degree angle downwards. With the right hand on top with fingers on the laces and the left hand below. You will then open to the right side and start the drop back crossing the left foot over the right and then crossing the right foot behind the left. At which point in time I gave them additional directions based on which stress situation was occurring. I said for the non-stress when you cross left over right I will say a target name and then when the right foot hits the ground for the last time you will plant and throw. For the stress situation, when you cross your left foot over their right foot, the first tennis ball will be thrown. When you cross behind the right foot to make the final drop step you must start moving to dodge the tennis balls and after the second tennis ball is thrown the target name will be said. You will then dodge the third tennis ball plant and throw to that target as fast as possible. Any questions?