

Sports, Exercise, and Health Science

Extended Essay

Title: A study of the effects of progressive muscle relaxation (PMR) on conversion rate in soccer penalty kicks at youth level

Research Question: How does progressive muscle relaxation (PMR) affect conversion rate in a soccer penalty shootout between two groups of male representative team players aged 16-17?

Word Count: 3823

Introduction

When an elimination soccer game ends without determining a winner, the teams conduct a penalty shootout. In a penalty, the player gets to take one shot on goal from 11 metres away, with only the goalkeeper allowed to defend it. The entire team and season's fate is decided with one simple kick.

At first glance, penalty kicks seem to be largely in favor of the shooter. Taken merely 11 metres away from the goal, and at an average shot speed of 110 kilometres per hour at professional level, the goalkeeper has only about 0.36 seconds to save the kick. Professional goalkeepers have an average reaction time of 0.15 seconds, and it takes 0.5 seconds on average to fully extend their body to make a save (Clegg 2016). This means that goalkeepers often do not have enough time to save the shot, and a well-placed penalty is mathematically impossible to stop.

Researchers at the University of Bath (Kerwin & Bray, 2006) identified the maximum range that goalkeepers can cover when fully extended, called the “diving envelope”. The part of the goal outside this range was called the “unsaveable zone”, 28% of the total goal area. Shots in this zone (the red area in Figure 1) were scored 80% of the time in their study, while shots in the diving envelope were scored only about 50%. Thus, all a player has to do is put the ball in the “unsaveable zone” for a near-guaranteed goal. Given that professional footballers are expected to be able to pass to their teammates' feet, a much smaller target, from across the field, a shot in the unsaveable zone is well within their capability.

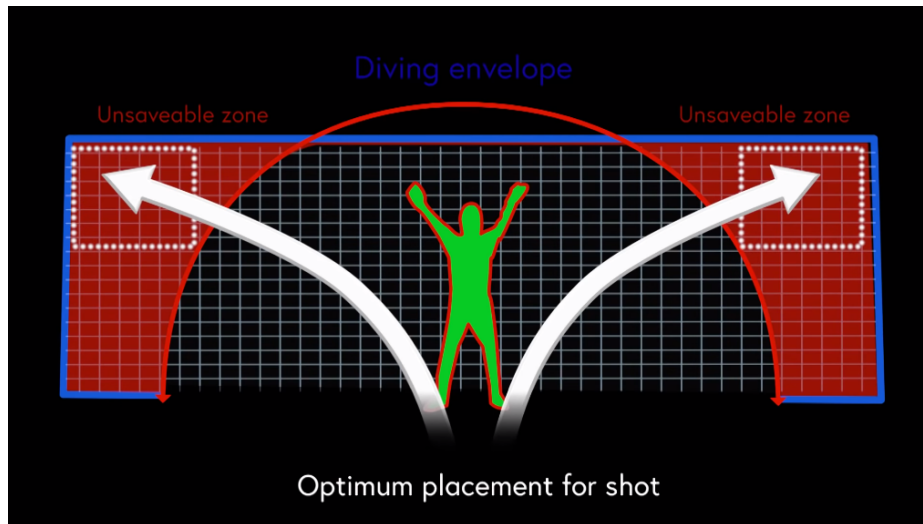


Figure 1: The “unsaveable zone” of the goal studied by the University of Bath (UniofBath 2014).

In practice, however, many players end up missing penalties due to the immense pressure on them to score disrupting their performance. Between 2016 and 2020, the penalty conversion rate in England, Spain, Italy, and Germany’s top soccer leagues was 75.7% (Schalter 2020). In that same time period, the penalty conversion rate in the Champions League, a higher-stakes competition that features the best clubs from those countries, was 71.9%.

My extensive passion for soccer led me to investigate further into the mental challenges penalty kicks create. I have 5 years of experience representing both club and school soccer teams, during which I missed a penalty in the final of a school soccer tournament. My personal experience of the stress impairing my ability to focus and shoot normally inspired me to further understand what occurred that influenced me to miss. Upon reading another Extended Essay (IBO, 2017) which studied how meditation affects accuracy in 10m pistol shooting, I was interested to see

how relaxation techniques could be applied to other sports as well. This extended essay provided a starting point for my research and experiment procedure.

A study by the Journal of Sports Sciences found that stress was the most influential factor in penalty kick conversions, over a player's technical ability or level of fatigue (Jordet et al., 2007). Studying 409 penalty shootouts in the World Cup, European Championship, and Copa America from 1976 to 2004, the study used the importance of the game (the further the team went in the tournament) and the decisiveness of the penalty (proximity to end of shootout) as indicators of stress.

In a shootout, whichever team scores more penalties out of 5 attempts wins. If they are tied after 5 attempts, whichever team scores more penalties out of 1 attempt wins (sudden death). The first penalty in each shootout had an 86.6% conversion rate, which decreased with each consecutive penalty. The sixth through ninth penalties, which were immediately decisive, had a 64.3% conversion rate. Additionally, there was a 10% decrease in conversion rate between the least (Copa America) and most prestigious (World Cup) tournaments. The prestige was determined by the average FIFA ranking of each country in the tournament. Other statistics, such as player position, age, and playing time, had a maximum of a 10% difference between the conversion rate of the first and sixth penalties. From these results, the study concluded that as stress on the player increases, the penalty conversion rate decreases significantly.

Their findings support a common sports psychology theory known as the Inverted-U theory, which states that there is an optimal level of arousal (anxiety) for peak athletic performance. Too little anxiety and the athlete has no motivation to perform well, while too much anxiety throws the athlete off their game. Since penalty kicks can decide the game, the player is likely to experience extreme levels of anxiety. In this case, the study found an inverse relationship between the player's anxiety going into the penalty and their resulting performance, which matches up on the right half of the bell curve as seen in Figure 2. As a player faces more pressure to score, they have more anxiety and thus a worse performance, shown by going from point A to point B on Figure 2.

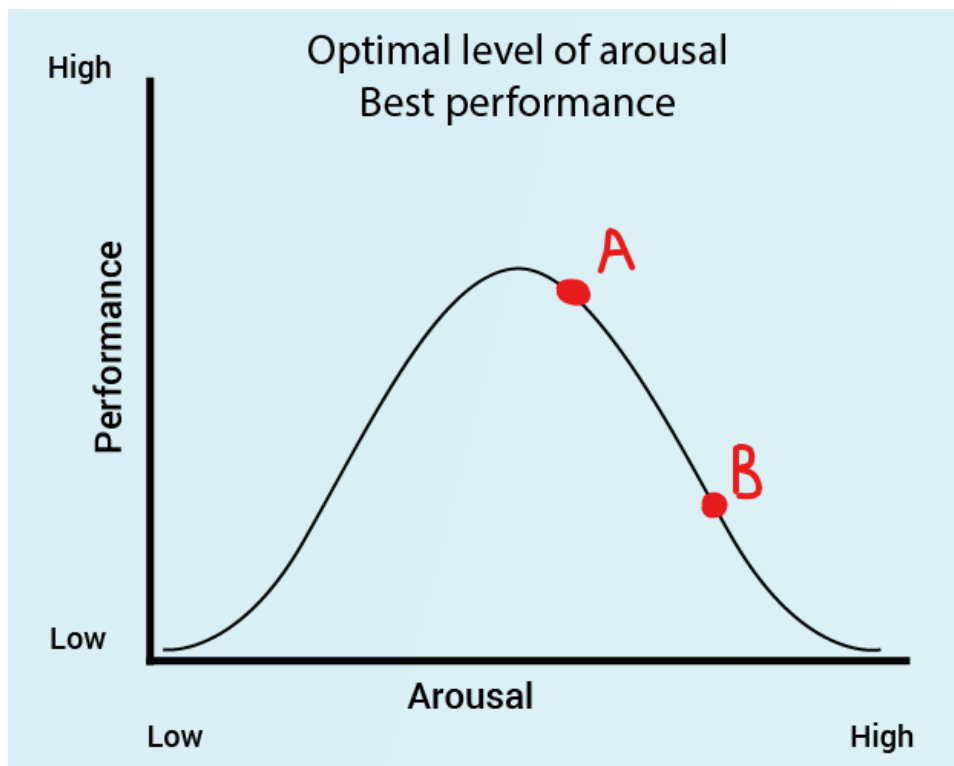


Figure 2: The Inverted-U theory (WJEC 2015) relating sport performance and level of arousal (anxiety).

There are two types of anxiety that can affect a footballer's performance: cognitive (the mental effects) and somatic (the physical effects). Cognitive anxiety can make a player both lose focus or overthink kicks that normally come routinely. Many players practice shooting until it is "muscle memory" (Oxford University 2017), so shooting comes instinctively in-game. This is useful in open motor skill situations such as open play, where the environment is constantly changing and there is little time to think. A penalty, on the other hand, is a closed motor skill in which the player can determine when they are ready to take the kick. In this situation, the player has lots of time to think, leading them to second-guess their instincts in an attempt to visualize the penalty. According to research done by Ehrlenspiel et al. (2013) "pressure increases conscious attention on the process of performance and that this in turn disrupts the automatic or overlearned nature of its execution". The same kicking motion that has come natural so many times fails to produce itself as the player does not trust their instincts under high pressure. A failure to stick to their instincts, their familiar method of shooting, leads to missing the shot.

The Journal of Sports Sciences 2007 study recommended that "practitioners work with players to reduce the perceived importance of each kick". Anxiety reduction techniques, such as progressive muscle relaxation, may help players block out the pressure and thus increase their conversion rate. The positive effects of such anxiety reduction techniques on sport performance are well documented at professional and collegiate level (Hernandez et al., 2016). College volleyball players who conducted 18 PMR sessions scored 1.5 points better on CSAI (Competitive State Anxiety Inventory) cognitive/somatic anxiety and self-confidence tests, both statistically significant at a 95% confidence level (Navaneethan et al., 2010).

Another study on college soccer and baseball players found that consistent yoga training, a similar relaxation technique, was able to increase players' flexibility and balance (Polsgrove et al., 2016). After 20 yoga sessions, the test group reached 1.8 inches further in a stretch and held a stork stand for 4 seconds longer, both statistically significant at a 95% confidence level. Muscle mobility is of interest as a successful penalty requires an accurate leg swing, which somatic stress can impair, explained below. The goal of my study was to examine whether the positive effects of PMR would also be seen at the youth level, where athletes may not have as much experience or confidence in their ability to score compared to adult and professional athletes.

Research question: How does progressive muscle relaxation (PMR) affect conversion rate in a soccer penalty shootout between two groups of male representative team players aged 16-17?

Hypothesis: There will be a positive correlation between time spent practicing PMR and penalty conversion rate.

Theoretical Background

PMR is an anxiety reduction technique that involves systematically tensing and relaxing all of the body's muscle groups one by one. This procedure, as outlined by Anxiety Canada (2019), takes about 15 minutes and is explained below:

1. Pick a muscle group to use.

2. Inhale deeply and flex the targeted muscles as hard as possible for about 5 seconds. Try not to flex any other muscles except the group targeted - this will get easier with practice.
3. Exhale and completely relax the muscles for about 15 seconds. Focus on the difference between the tension and the relaxation. This is the most important part of the whole exercise.
4. Repeat with another muscle group until you have flexed all major muscle groups in your body.

The somatic stress of penalties can cause players to tense up, and not perform as well. In a regular kick, your muscles are relaxed and only become tense just before you make contact with the ball, to give the kick power. However, in stressful situations, your muscles tense up as part of your body's fight-or-flight response (American Psychological Association 2018). This makes your muscles tense long before you make contact with the ball, which makes it harder to swing your foot properly than if your muscles were relaxed like normal. This can decrease the speed of the kick, which decreases its power, or the player may unintentionally kick the wrong part of the ball, which changes both the power and trajectory of the shot (Bauer et al., n.d.). By practicing PMR, players learn to realize when their muscles are tense from stress, and practice how to relax those muscles to perform better so they can do it on command (Anxiety Canada, 2019). They will be able to control their anxiety better and thus perform better in a stressful environment such as a penalty shootout.

Experiment

The study used 15 male volunteers between the ages of 16 to 17 from a local youth club, each having at least 5 years of experience playing club soccer. Before starting the study, player and parent participation and media consent was obtained and the test group was given a presentation on PMR. To ensure the safety of each participant, they completed the PAR-Q test to permit them for vigorous physical training, even though PMR is a relaxation technique and is not vigorous in nature.

The study's procedure is outlined below:

1. On September 9th, a mock penalty shootout was conducted.
 - Each player takes 3 penalties. For each penalty miss, the entire team (except for the goalkeeper) will run 1 suicide run, the length of the field (about 100 metres) at the end of the shootout.
2. The team will then be split into a test group who will practice PMR, and a control group.
 - Players were randomly assigned to a group. Each group has an equal amount of defenders, midfielders, and forwards, to make the shooting skill of each group equal.
 - Both groups will attempt 3 penalties a week during team practices for 3 weeks.
 - The test group will also do PMR for 15 minutes every day for 3 weeks.
3. Another shootout under the same conditions on September 30th will be conducted and the shootouts' conversion rates will be compared for any improvements.



Figure 4: The experimental set-up. The penalty spot was indicated by the yellow cone.

The running penalty makes individual mistakes negatively affect the whole team, which is analogous to the penalties in a shootout that, if missed, lose the team the game. This draws upon a cognitive bias called loss aversion, which states that the psychological effect of losing outweighs that of an equivalent win (The Decision Lab 2020). In the 2007 study, penalties to win the game had a 13% conversion rate improvement while penalties to keep the team alive had a 19% conversion rate decrease (Jordet et al., 2007). The goal of using this bias is to help simulate the intense pressure of a real penalty shootout. However, it is important to note that the stress on the players is not any higher than they would experience in a competitive game during their season, and the running punishment was not more demanding than their regular fitness training.

A test duration of 21 PMR sessions (every day for 3 weeks) was chosen to match the length of the previous anxiety reduction sport studies. The team had been warming up for about 15 minutes prior to the start of both shootouts. This ensures that their penalty kick was not their first time shooting the ball, which is similar to real-life shootouts which happen at the end of a game. The experiment setup is shown in Figure 4. Ideally, the shootout would occur with white spray painted pitch markings as required by IFAB (IFAB 2020), but these were not available to use.

Results

Test Group							
		First shootout			Second shootout		
Name	Position	P1	P2	P3	P1	P2	P3
Player 1	D	score	score	score	score	score	score
Player 2	D	score	score	miss	miss	score	score
Player 3	D	score	score	score	score	score	score
Player 4	M	save	miss	score	score	score	miss
Player 5	M	score	score	score	score	score	score
Player 6	F	miss	miss	miss	miss	score	score
Player 7	F	score	miss	score	score	score	score
		Conversion rate = 66.7%			Conversion rate = 85.7%		
Control group							
		First shootout			Second shootout		
Name	Position	P1	P2	P3	P1	P2	P3
Player 9	D	score	score	miss	score	score	score
Player 10	D	score	score	miss	score	score	miss
Player 11	D	score	miss	score	miss	score	score
Player 12	M	score	save	score	score	score	score
Player 13	M	score	score	save	score	score	score
Player 14	F	score	score	score	score	save	score
Player 15	F	score	score	miss	miss	score	score
		Conversion rate = 71.4%			Conversion rate = 81.0%		

Figure 5: This table displays the outcome of all penalties taken in the study and the overall conversion rate for each team in each shootout. The first shootout is before PMR training and the second shootout is after.

Analysis and Conclusion

The conversion rate was calculated using the following formula:

$$(\text{penalties scored} / \text{total penalties}) \times 100\% = \text{conversion rate}$$

Sample calculation for first shootout (control group):

$$(14/21) \times 100\% = 66.7\%$$

Goalkeeper save rate formula:

$$(\text{penalties saved} / \text{shots on target}) \times 100\% = \text{save rate}$$

$$(4/68) \times 100\% = 5.88\%$$

Z-test to determine statistical significance

The z-test (NCSS, n.d.) allows us to determine whether the test group's improvement from the first to the second shootout is statistically significant. P_1 and P_2 are the improvement in scoring probability for the test and control group, respectively, from the first to the second shootout. F and i are the number of penalties scored in the final and initial shootout, and n is the number of penalties attempted in each shootout.

$$p_1 = (f - i) / n \quad p_2 = (f - i) / n$$

$$p_1 = (18 - 14) / 21 \quad p_2 = (17 - 15) / 21$$

$$p_1 = 0.190 \quad p_2 = 0.0952$$

$$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$$

$$p = \frac{21(0.190) + 21(0.0952)}{21 + 21}$$

$$p = 0.143$$

$$Z = \frac{p_1 - p_2}{\sqrt{p(1-p)(1/n_1 + 1/n_2)}}$$

$$Z = \frac{0.190 - 0.0952}{\sqrt{0.143(1 - 0.143)(1/21 + 1/21)}}$$

$$z = 0.882$$

On a z-table, our value for z matches up to a confidence level of 81.1%. This means that there was a 18.9% probability our value was obtained through random error. The scientific community requires a maximum of 5% random error probability to reject the null hypothesis and accept the hypothesis that this value was caused intentionally and not by chance. Since our value is higher, the test group's improvement was not statistically significant and the results are not definitive.

The results show a positive correlation between PMR training time and penalty conversion rate: the test group who performed PMR training experienced a 19% increase in conversion rate between the two penalty shootouts, compared to the control group who experienced a 9.6% conversion rate increase. This supports the hypothesis that PMR training will cause an increase in penalty conversion rate. This is because PMR training allows players to release the stress that is above the optimal level in the Inverted-U theory to have a better athletic performance, going

from point B to point A in Figure 2. However, since the recorded improvement is not statistically significant, a larger study with more participants is required to accept the hypothesis.

It must be noted that for sample sizes under 30, a t-test is recommended over a z-test (Sauro 2013). Our study consisted of 15 players total. However, since we had binomial instead of continuous data, we could not generate a variance to use t-tests. Using tests designed for smaller sample sizes may have given us an even higher confidence value and allowed us to reject the null hypothesis. For example, the yoga study done by Polsgrove et al. (2016) only studied 26 participants, yet used a t-test to find a statistically significant improvement.

Recording shot speed and placement (near the “unsaveable zone”) can be used to quantify the quality of a shot and use t-tests. Studies have found that the velocity and accuracy of a penalty shot are inversely related, however, and the best penalty results occur from a balance of the two (Bauer et al., 2019). If the goalkeeper over commits to one side, a simple shot in the middle would also work despite not being quantitatively a “high-quality” shot by our test. This is a common tactic at professional level (Woodcock 2018) to outsmart keepers preemptively diving to one side in expectations of a “high-quality” penalty kick.

Evaluation

Firstly, to obtain more solid and precise results, a larger sample size is necessary. Naturally, a small sample group of only 15 players will have a higher chance of random error and anomalies

than a larger group. For example, one player in the test group missed all of his penalties in the first shootout, which is drastically below the average conversion rate of 66.7% for that shootout. However, the COVID-19 pandemic made it difficult to find multiple clubs that were able to safely hold practices.

Also, testing only one club's players in one demographic does not fairly represent the abilities of Canadian youth and grassroots players as a whole. A more diverse selection of participants from various age groups and genders would provide insight on how stress affects players of different ages and genders, a further topic for investigation. According to Anxiety Canada (2019), those who conduct PMR sessions begin to see results after 2 weeks. Given that the study only ran for 3 weeks, the effects of PMR training would have only been active for 1 week.

Comparing the effects of PMR on penalty kicks with alternate anxiety reduction techniques such as yoga or meditation could lead to a better understanding of which type of stress has the greater effect on performance. Yoga tends to focus on body movement, and thus would better control cognitive anxiety, whereas meditation focuses on the mind and would better control somatic anxiety. PMR combines both by practicing both mind and muscle relaxation simultaneously.

A longer test duration would give the participants even more time to practice controlling anxiety which would create an even larger increase in conversion rate. While the previous anxiety sports studies used training every other day over a longer trial period, COVID-19 restrictions would

potentially interrupt a longer study. It was noted the team stopped practicing a week after the experiment's end to comply with municipal pandemic restrictions.

The greatest difficulty in the experiment was simulating the same pressure of that of a championship game. Since all the players knew each other, this could have created an informal environment which would decrease the pressure on them to score. To make it more realistic, an audience or a monetary prize for those with the highest conversion rates would simulate the features of a real-life tournament. Unfortunately, these were not available for the experiment. A possible systematic error would be not giving a reward or punishment to the goalkeeper for saving shots, as the goalkeeper is also subject to their own level of stress which affects their performance. As a result, the goalkeeper had no incentive to save the penalties which could skew the conversion rates higher than they would have been under ideal conditions.

Moreover, in real-life penalty shootouts, players typically only take one penalty, giving them only one chance to succeed. Players only take another penalty if everyone on the team has taken one and the shootout has still not been decided, which is a rare occurrence. For example, in the Journal of Sports Science study spanning 28 years of international tournaments, there were no recorded instances of a player taking a second kick. Thus, a balance had to be reached between having enough data points without decreasing the pressure on each penalty. The players gain experience with each shot as well, becoming more familiar with the specific action shooting a penalty. The first penalty could have acted as a warm-up to the second and third ones, which

would skew the data upwards. This is reflected especially in the second shootout: 4 players in total missed their first penalty, only to score the next two.

Additionally, the team only had one goalkeeper, who could have gotten tired as the shootout goes on, which may skew the conversion rates to be higher than they actually are as he could not make a full-effort save in the later penalties. Although the goalkeeper is also familiar with the players which would skew the conversion rates lower as he may know where they typically shoot, professional goalkeepers are typically instructed on the shooting habits of their opponents in the case of a penalty shootout as well (Minkus 2017). Goalkeepers from the same team were used so that the players and goalkeeper would be approximately at the same skill level. However, it should be noted that the goalkeeper's save rate throughout the experiment was 5.88%, which is much lower than values seen at the professional level, typically around 17.5% (InStat 2020). This suggests that the goalkeeper was below the team's skill level, which may have skewed the conversion values upwards.

The results of this study can spark a larger conversation about applying methods of controlling stress in sport. For example, this study was conducted with participants 1 year away from being considered an adult. Given that club youth academies run programs for players as young as the age of 12, another study could investigate if the same effects would be seen at that age, who may not have as much playing experience and mental fortitude as teenagers. PMR training can be useful in other sports that involve repetitive closed motor skill situations, such as golf, archery, or a free throw in basketball.

It can be noted that many of the skills used in a shootout can also be used in regular gameplay.

Although regular gameplay does not attribute the outcome of the game onto one kick, many players still underperform in regulation time in the final of an important tournament, often for the same reasons they fail in penalty shootouts (Ehrlenspiel et al., 2013). Additionally, the positive effects of anxiety reduction techniques are not limited to sport. For example, surgeons repeat precise procedures honed through years of practice when operating. Just like in a penalty kick, there is a high amount of pressure on a thoroughly practiced task. New research investigating modern training methods for surgeons such as box trainers and virtual reality simulations, emphasize the importance of muscle memory. According to Papanikolaou et al., (2019) “simulation training allows trainees ... to repeat surgical tasks multiple times so as to establish muscle memory”. Adding PMR practice to a surgeon’s training could improve surgery performance and provide a lasting benefit to society beyond the range of sports.

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