The Effects of Strength and Conditioning Programs on In-Game Performance of Male College Lacrosse Players

by

Jeremy Field

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Abstract

The purpose of this study was to determine the impact on the performance of men's lacrosse players after participating in a rigorous fitness regimen. The measurement tools were a pre- and post-test measuring mile times, dips, bench press and pull-ups, as well as pre- and post-surveys with the coaching staff. This study involved use of a quasi-experimental design to measure the change in fitness levels and observed performance. Improvements in fitness metrics showed correlations with improved on-field performance. There is still room for research in this field, especially involving control groups and more structured testing conditions.

CHAPTER I

INTRODUCTION

While improved physical performance, especially with regard to improved aerobic and muscular performance, has a strong positive correlation with on-field performance, it must be determined what special considerations need to be made for translating the success in the weight room onto the playing field. The ideal lacrosse player strives to reach a physicality that incorporates "speed, agility, strength, endurance, and lean body composition" (Gutowski & Rosene, 2011, p. 17). This body type is common in athletics, especially with field sport players, so many comparisons can be drawn from the performance of athletes in other sports. As lacrosse athletes must possess a high degree of "motor skill, agility, speed, strength, flexibility, and both aerobic and anaerobic capacity," that makes lacrosse players "similar to those in basketball, football, ice hockey, field hockey, and soccer" (McCleod, Hunter, & Etchison 1983, p. 390). One difference, however, is that lacrosse players tend to have a lower body fat percentage compared to other athletes such as football, basketball and ice hockey players due to the nature of the sport (Shaver, 1980).

Statement of the Problem

In an effort to improve on-field performance, teams seek any edge possible to increase the probability of success. There are currently no methods to find a relationship between improvement in weight room testing and success on the field.

Hypothesis

Physical improvement, as measured by off-field measurements attained from weight room testing, including dips, pull-ups, bench press and mile run time, cannot be related to improvements in players' on-field performance.

Operational Definitions

The independent variable of this study is the amount of improvement in weight room measurements attained from the standard workout regimen given to men's lacrosse players. The dependent variable is the change in on-field performance by each player. The weight room measurements used in this survey are one mile run, pull-ups, bench press and dips. A mile run is a timed run on an outdoor track. A single pull-up is measured as the athlete starting from the vertical position and pulling himself up on a bar until his elbows create a 90-degree angle. Dips are the inverse of pull-ups, as the athlete starts vertical with the bar around waist high and lowers his body until his elbows create a 90-degree angle. The bench press takes place when the athlete, flat on his back, brings a bar weight the same as his body weight, down to his chest and back up, fully extending his elbows.

Velocity represents the top speed a player can reach while sprinting. Sprint performance is the combination of acceleration and velocity, showing a total picture of how an athlete goes at full speed. Operationally, one can determine sprint performance by testing how quickly athletes can cover a certain amount of ground. Since acceleration to top speed doesn't take much distance for elite athletes, velocity becomes more important over longer distances. For example, a runner with better acceleration can beat an opponent with a higher top velocity over the first five yards, but after both runners reach top speed, he will lose ground to his opponent with each step. Since the majority of sprints in each game are battles over short distances, it is more important to have acceleration than velocity (Wisloff, Castagna, Helgerud, Jones, & Hoff, 2004).

CHAPTER II

REVIEW OF THE LITERATURE

This literature review explores the issues related to college level lacrosse players' physical fitness and its relationship with the improvement of players' on-field performance. Section one discusses strength and conditioning and their relationship to lacrosse. Section two focuses on lacrosse and the skills necessary to succeed on the playing field. The final section discusses how to alter fitness plans in order to improve performance.

Role of Strength and Conditioning

While the rallying cry of youth athletic coaches has been "practice makes perfect," there is an inherent advantage that physically fit athletes hold over their less fit counterparts. It has been determined "Significant correlations were found between velocity…and most strength and power measures" (Lockie, Murphy, Knight, & Janse de Jonge, 2011, p. 2704). In addition, further research indicates that by taking measures of lower-body strength, a significant relationship with acceleration, velocity and sprint performance, when corrected for body mass, can be found. Further, lower-body power appears to impact acceleration and sprinting velocity (Brechue, Mayhew, & Piper 2010). In order to improve lower-body power, which will in turn impact acceleration and velocity, athletes should perform resistance training to improve performance. (Blazevich & Jenkins, 2002).

Lacrosse players were also listed as "above average in some indices of maximal aerobic power" and "had higher maximal power, mean power, and total work output, collectively, than reported for other college athletes" (Steinhagen, Meyers, Erickson, Noble, & Richardson, 1998, p. 226). This is a major issue, as it has been ascertained that low aerobic power leads to fatigue (McCleod, 1983). Since fatigue is a major issue in athletics, there have been attempts to find the

best methods of training that will increase endurance and limit fatigue. Recently, it was found that interval training improved fatigability and mean power output more than slower, continuous training. While continuous training is still considered useful for increasing endurance, the nature of field sports makes it such that athletes should train with interval training to increase their overall endurance (Tanisho & Hirakawa, 2009). While aerobic issues are detrimental to the performance of lacrosse players, interval training also provides the benefit of improving anaerobic performance. This is essential, as it has been found that "approximately 70% of energy consumption during lacrosse activity occurs through anaerobic pathways whereas 30% occurs through aerobic pathways" in field sports (Pistilli, Ginther, & Larsen, 2008, p. 32).

With it being established that high-intensity training creates greater gains in strength, anaerobic power in athletes, the focus must be on working on exercise regimens that are higher intensity, which will boost performance and allow players to maintain the gains made for a prolonged time even after training ceases during the season (Fatouros, Kambas, Katrabasas, Nikolaidis, Chatzinikolaou, Leontsini, & Taxildarism, 2005). In addition, adding in plyometric exercise to resistance training can be helpful, as it has been concluded that the two training methods used in conjunction are more useful than either is individually (Carpinelli, 2002, p. 320). The combination of plyometrics, which is the process or rapidly contracting and expanding muscles to improve explosion and acceleration, and the resistance training as suggested by Blazevich (2002) above lead to the best improvement in performance.

Lacrosse and Training

As lacrosse is a newer sport with less coverage than many others, seeking out answers from research in other sports can be useful in determining the type of connections between skills and performance on the field. Looking at soccer, a sport that may be the most similar to lacrosse

physicality than any other, research was able to find a strong correlation between maximal strength, sprinting, and jumping performance in elite soccer players, meaning that a total physicality is necessary for successful performance on the field (Wisloff, 2004).

While the similarities between soccer players and lacrosse players are numerous, a major difference between the two sports includes the role of different positions on the field for the two sports. For the purposes of this research, goalkeepers must be excluded, as athletes playing that position have a very unique set of skills that don't necessarily mirror those of their field-player counterparts. Field players can be divided into three categories: offense, midfield and defense. For the purposes of this study, the terms attack, forward and offense are synonymous, as are backs with defense. The intent of the offense is to try and score goals by legally putting the ball into the net. The job of the defense is to prevent the offense from scoring by taking the ball away from them before they can put the ball in the net. Midfielders assist both the offense and defense in their respective goals by playing on both sides of the field (Gutowski & Rosene, 2011).

The differences are far more distinct in lacrosse between the physical build of the different positions in lacrosse than soccer, which contributes to the different objectives for each group of athletes. In soccer, there is a free-flowing game with very limited interruption and the ability for any player to go to any part of the field at any given time, meaning that a back can try and score or forwards can come back to try and defend. In lacrosse, players must keep at least three players on each side of the field at any given time, so there is much less fluidity in the positional assignments (Gutowski & Rosene, 2011).

Starting with offense, attackers in lacrosse rely on speed, agility, and elite stick skills most in order to attempt to score on the opposition. Offense in lacrosse is often similar to a "half-court offense" in basketball, in which the offensive team surrounds the net and attempts to

penetrate the defense, which stands between the ball and the net. For this reason, short bursts to sneak between defenders are the most important physical factor in creating scoring opportunities. Attackmen are generally smaller and carry less body mass than any of their field position counterparts, as strength is not as necessary of a skill (Gutowski & Rosene, 2011).

On the other side of that equation, defenders also use speed and agility to attempt to stay between the attackers and the goal, but the significant difference is that defending requires greater strength, to physically keep the attackers away and to attempt to strip them of the ball in order to regain possession for their team (Gutowski & Rosene, 2011). As lacrosse is considered a collision sport, legal contact is encouraged on defense as a method of preventing the opposing team from scoring. For this reason, defenders generally are the most physically intimidating players on the field, as they focus on increasing their size and strength, while also working on their lateral quickness to improve defensive range.

Midfield is often considered to be the most physically demanding position on the field, as those who play in the midfield are forced to play on both the offensive and defensive sides of the field, requiring both the physical traits of both an attacker and defender, while also attempting to limit fatigue, as midfielders are required to do more running than any other position (Romas & Isles, 1986, p. 43). “The midfielder as a result is required to cover the most running distance while assisting ball movement from defense to offense and therefore needs speed and great stamina. The midfielder usually possesses the greatest fitness level out of all the positions”. The unique aspect of the position requires an “intrinsic combination of muscular strength and endurance”, which creates the ability to “explosively adjust directions” while seamlessly transitioning from the offensive skillset into defensive mode as a midfielder. (Gutowski & Rosene, 2011, p. 17).

Strength and Conditioning Plan

With knowledge of the skills, traits and body mechanics that are necessary for successful lacrosse performance, one is able to conclude the types of exercises necessary that, when implemented, will aid in the progression of our athletes. one must work on lower body strength to improve sprinting, upper body strength for defenders, use plyometric exercises to create explosion and do interval exercises to help endurance (Gutowski & Rosene, 2011).

To improve sprinting the focus should be on improivng lower-body strength to increase acceleration and top speed. Among the exercises that would be included in a conditioning plan include squats, which the athletes place weight on their shoulders and bend their knees and push back up. In addition, lunges, in which the athlete puts weight on their shoulder or at their sides and steps forward, with one leg and bends their back knee, would be included. Numerous short burst non-resistance exercises would be combined to get the most out of our exercises (Pistilli et al., 2008).

Upper body would be incorporated for midfielders and attackers as well, working more with core exercises than anything else. The core is described as the center of the body, being the abs, chest, shoulders and more. Crunches and sit-ups will work the core, often with weight included. Planking, the process of holding a position of holding oneself up like board by their toes and forearms, is another exercise that helps the general core. To improve lacrosse-focused muscles, weighted swings would be included in our regimen. This exercise is the process of holding on to a stick attached to a pull-weight and swinging it like a baseball bat or lacrosse stick, slowly. This mimics the natural movement of a lacrosse swing and will increase the velocity of shots and passes, making it more natural for an athlete (Pistilli et al., 2008).

Summary

It is possible to create a plan to increase lacrosse performance and create a competitive advantage by having players train in a way that improves their performance in position-based exercises. By focusing the exercises on skills that players will use routinely on the field, an increase in velocity, acceleration, strength and endurance, all of which have lacrosse-specific goals, can occur. There is a list of exercises that have been shown to improve each of these physical measures and correlations between the measures and on-field performance have been found. Combined, that ensures that training regimens can be created to help athletes.

CHAPTER III

METHODS

The purpose of this study was to examine the relationship between changes in the performance in weight room testing and the change in performance on the field for men's lacrosse players. The relationship between changes in pre- and post-testing for athletes in a mile run, pull-ups, dips and bench press was compared to subjective grades for lacrosse performance. On-field performance was a subjective measure given by the coaching staff in regards to physical condition, playing skill including physical traits as well as talent, and potential to improve due to a number of factors.

Design

The study was a quasi-experimental design using a pre- and post-test for fitness, as designed by the lacrosse coaches, and a pre- and post-survey regarding performance.

Participants

The participants were student-athletes on a Division III men's lacrosse roster. A convenience sample was utilized in this study, as the team was pre-selected before the study took place. The team consisted of 41 members, ranging in age from 18 to 22 years old at the time of the study. By the conclusion of the study, three members had left the team for a variety of reasons and were never administered post-tests or post-surveys, leaving the study with 38 members.

Instruments

There were two instruments used for data collection in this study. The first was physical fitness tests in the following categories: one mile run, pull-ups, bench press and dips. The second

was a self-created pre-and post-survey of the coaches used to rate player performance based on a number of factors.

Procedure

The purpose of this study was to judge the change in on-field performance as compared to the change in fitness performance testing over time. In order to judge fitness testing, all 37 players completed the same four fitness tests on the same day, completed a fitness program throughout the fall, then took the same fitness test four months after the original test. For the one-mile run, the athletes were all required to run four times around an outdoor track in conditions without precipitation, although the temperature was much colder for the post-test, with significant winds. A pull-up was defined as one complete movement, going from having straightened arms to having the chin above the bar. A push-up was defined as one complete movement going from the stationary plank position, down to 90-degree angled elbows, and back up to the starting position. A dip was defined as starting from the vertical position, down to 90-degree angled elbows, and back up to the starting position.

The coaching survey consisted of three questions, in which the coaches replied with a number from one to ten. The questions consisted of rating the players' physical shape, lacrosse performance and potential lacrosse performance. These ratings were subjective, in the eyes of the coaches, who had watched the players frequently throughout the year.

CHAPTER IV

RESULTS

This study examines the relationship between the change in lacrosse performance and the change in physical fitness measures (pull-ups, dips, bench press and mile run).

Pre and Post data were gathered on student-athletes on a Division III men's lacrosse roster. Table 1 displays the data related to the pre and post measures associated with bench presses, dips, pull-ups, and the mile run.

Table 1

Dependent t Analysis of Bench Presses, Dips, Pull-ups, and the Mile Run

Dependent Measures	Mean	N	Std. Deviation
Bench Press			
Pre	9.53	36	5.863
Post	10.53	36	4.843
Dips			
Pre	31.08	37	8.335
Post	36.86	37	8.842
Pull-ups			
Pre	23.30	37	7.742
Post	28.00	37	7.219
Mile Run			
Pre	5.95	37	.449
Post	7.87	37	11.016

Statistically significant findings were obtained using the dependent t test (also known as the paired t test). Table 2 shows that student performance was significantly different on all measures except the mile run. That is, student's performed significantly better on the post measures than the pre-measures.

Table 2

Dependent t –tests of Significance on Pre and Post Measures,
Bench Presses, Dips, Pull-ups, and the Mile Run

Dependent Measures	Mean Difference	t	df	Sig. (2-tailed)
Bench Press Pre to Post	-1.00	-2.426	35	.021
Dips Pre to Post	-5.784	-6.028	36	.000
Pull-ups Pre to Post	.4703	-6.652	36	.000
Mile Run Pre to Post	-1.916	-1.056	36	.298

Table 3 shows the correlations among the measures from Tables 1. Significant correlations were found between bench change and dip change; bench change and pull-up change; physical change and lacrosse change; physical change and potential change; and lacrosse change and potential change. These correlations indicate that several of the dependent measures are related.

Table 3

Correlations Among the Different Dependent Measures

		Mile Change	Bench Change	Dip Change	Pull Change	Change Physical	Change Lacrosse	Change Potential
Mile Change	Pearson Correlation	1	.153	.135	-.312	.150	.072	.090
	Sig. (2-tailed)		.375	.427	.060	.382	.675	.603
	N	37	36	37	37	36	36	36
Bench Change	Pearson Correlation	.153	1	**-.384***	**-.456****	-.051	-.004	-.029
	Sig. (2-tailed)	.375		.021	.005	.772	.983	.871
	N	36	36	36	36	35	35	35
Dip Change	Pearson Correlation	.135	-.384*	1	.197	.123	.114	.043
	Sig. (2-tailed)	.427	.021		.244	.474	.506	.804
	N	37	36	37	37	36	36	36
Pull Change	Pearson Correlation	-.312	-.456**	.197	1	-.002	.027	.033
	Sig. (2-tailed)	.060	.005	.244		.989	.876	.851
	N	37	36	37	37	36	36	36
Change Physical	Pearson Correlation	.150	-.051	.123	-.002	1	**.789****	**.713****
	Sig. (2-tailed)	.382	.772	.474	.989		.000	.000
	N	36	35	36	36	37	37	37
Change Lacrosse	Pearson Correlation	.072	-.004	.114	.027	.789**	1	**.842****
	Sig. (2-tailed)	.675	.983	.506	.876	.000		.000
	N	36	35	36	36	37	37	37
Change Potential	Pearson Correlation	.090	-.029	.043	.033	.713**	.842**	1
	Sig. (2-tailed)	.603	.871	.804	.851	.000	.000	
	N	36	35	36	36	37	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4 shows the means and standard deviation on the self-created pre-and post-survey of the coaches' ratings of player performance.

Table 4

Dependent t analysis of Coaches' Survey on Pre to Post Physical, Pre to Post Lacrosse and Pre to Post Potential

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Physical	5.30	37	2.296	.377
	Post-Physical	5.95	37	2.147	.353
Pair 2	Pre-Lacrosse	5.76	37	2.350	.386
	Post-Lacrosse	6.14	37	2.162	.355
Pair 3	Pre-Potential	6.41	37	2.533	.416
	Post-Potential	6.46	37	2.280	.375

The dependent t test, also known as the paired t test was used to examine whether there was any significant differences in the coaches pre-post survey ratings of student performance. Table 5 shows that student performance was significantly different on the Physical and Lacrosse performance questions. That is, student's performance was judged significantly better on the Physical and Lacrosse ratings.

Table 5

Mean and Standard Deviation Changes Between Coaches' Survey on Pre to Post Physical, Pre to Post Lacrosse and Pre to Post Potential

		Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Pre-Physical Post-Physical	-.649	1.296	-3.045	36	.004
Pair 2	Pre-Lacrosse Post-Lacrosse	-.378	1.139	-2.021	36	.051
Pair 3	Pre-Potential Post-Potential	-.054	1.224	-.269	36	.790

CHAPTER V

DISCUSSION

The purpose of this study was to determine if a relationship could be found between lacrosse performance and weight room measurements such as dips, pull-ups, bench press and mile run. The subjective lacrosse performance rating was compared with pre- and post-test data for lacrosse players in those four fitness tests.

The null hypothesis suggesting that no relationship exists between has not been supported. There is some evidence that an alternative hypothesis would be supported. Using the sample of 37 athletes, it was determined that there was a significant correlation between improving in one fitness test and improving in the other fitness tests. An improvement in bench press was found to have a significant correlation to improvement in dips and pull-ups. There was also a strong positive correlation found between perceived physical improvement from the coaching staff and improved lacrosse skill and potential.

In the physical fitness testing, there was found to be a statistically significant improvement in the group's bench press, pull-up and dip measurements. In the coaches' survey, a statistically significant increase in physical performance grades was observed.

Implications and Theoretical Consequences

The correlations found would be valuable to a coach, as it indicates that there likely is a relationship between weight room metrics and improved performance on the field by the players.

These findings would put more emphasis on weight room training by coaches seeking an edge on the field.

In addition, the correlations between improvements in three of the physical fitness tests suggests that improving one will tend to lead to improving the others, which could be useful if a specific skill is needed.

Threats to Validity

Due to the nature of this survey, there are significant threats to the validity. There are two factors which may threaten the validity of a study. The first are external threats, which involve factors that can make findings less valid for generalizations beyond the specific sample and situation in this research. The other threats are internal. These are errors of bias due to the study itself.

The first external threat is that the sample is limited to one team at one college with no control group and utilizing a survey. Second, the sample size of the survey, 37, is reasonable but limited by the sample type. Some athletes didn't participate in each event, so the sample size was as low as 35. In addition, the fact that all of these players are from the same area and are all white, mostly from middle- or upper-class backgrounds may limit the usefulness of applying study this to other groups.

In terms of internal validity with the players themselves, threats include injury, illness, change in diet, change in mood, or even weather on certain testing days. In regards to the

surveys, coaches will inherently have bias. The surveys the coaching staff filled out may have been altered based on mood, recent actions of a player or haste. While the relationship between physical improvement and lacrosse improvement was statistically significant in the survey, it's possible that the coach boosted up rankings of certain players. While the improvements on the survey tend to match the improvement on the testing, while not statistically significant, it shows the coaches did a fairly good job with the survey.

Selection bias may exist, as the team was an especially hard-working and focused team, possibly overstating the expected improvement by an average team. Experimenter bias may have also occurred, as the coach possibly had favorites on the team, whether he realized it or not. In addition, there was no control group for the physical fitness regimen, as the coaches weren't willing to risk a potential lack of improvement from players by having them sit out from weight training.

Other situational effects, such as timing, noise and pressure may have played a part in the findings. If the wind was blowing harder one day than another it might change mile run times a significant amount. In addition, athletes may have intentionally posted poor scores in the pre-test to make it seem as though they improved over the course of the fall. Any other threats to an athlete's performance, such as equipment issues, would also factor into the validity.

Connections to Previous Studies

As Gutkowski & Rosene (2011) stressed frequently, the body of a lacrosse player has certain characters that make it more desirable on the field. By using weight training, the athletes were able to improve maximal power, mean power, and total work output (Steinhagen et al., 1998). Also, as Lockie et al. (2011) suggested, power, strength and fitness have a significant correlation with velocity, which is a major component of successful lacrosse physicality, which could go towards explaining why the athletes with improved fitness measures tended to improve in the coaches' survey. Steinhagen (1998) said that this aerobic increase leads to higher power outputs as well, which minimizes fatigue (McCleod et al., 1983).

The largest contribution to the research of men's lacrosse and fitness previously came from Gutowski & Rosene (2011), who went into great detail describing the position-specific physical needs, explaining how these increased metrics in the players ultimately led to improved lacrosse ability, regardless of position. In addition, as Wisloff et al. (2004) discussed, the physicality of lacrosse relates to other sports. Using this knowledge, Wisloff's opinion about the relationship between the two can be supported and be used help apply it with other sports.

Implications for Future Research

With this study completed, future research can manipulate the conditions such that a future study will have fewer threats to validity. For example, a researcher can have a control group that does not engage in a fitness regimen to compare to an experimental group. The mile

run can be done indoors to prevent weather issues from affecting the results on that test. Diet and equipment can also be regulated as to level the playing field for all participants.

In regards to the survey, the researcher can find judges who are further removed from the situation to give less biased opinions on the athletes.

Conclusions

While there are threats to the validity, there are potential takeaways from this survey. The correlation between improved bench press performance and dips and pull-ups is very useful to coaches and athletes alike. This connection has broad appeal, as upper-body fitness is an important aspects of plenty of sports and numerous activities. Those seeking to improve their performance in dips and pull-ups can use the bench press to do so.

The most important finding is the significance at the 0.01 level between improved physical performance and improved lacrosse skill and potential. This lends credence to the intense physical training regimen that coaches put athletes through in the offseason. In addition, the exercises that were measured also seem to indicate a relationship between upper-body strength and improved lacrosse performance, helping coaches hone in on specific exercises that will help athletes improve lacrosse ability and potential in the future.

In the future, a similar study could give more complete results with fewer threats to validity, namely having a control group of those that do not participate in a weight-room exercise regimen and just compete in practices. This would give a more concrete look at comparisons

between groups, but with the level of significance in the correlations in this survey, one could expect similar results with a control.

REFERENCES

Blazevich, A.J. & Jenkins, D.G. (2002) Effect of the movement speed of resistance training exercises on sprint and strength performance in concurrently training elite junior sprinters. *Journal of Sports Sciences, 20*, 981-990.

Brechue, W. F., Mayhew, J. L., & Piper, F. C. (2010). Characteristics of sprint performance in college football players. *Journal of Strength & Conditioning Research, 24(5)*, 1169-1178.

Carpinelli, R. N. (2002). Berger in retrospect: Effect of varied weight training programmes on strength. *Journal of Sports Science and Medicine, 6,* 319-324.

Fatouros, I. G., Kambas, A., Katrabasas, I., Nikolaidis, K., Chatzinikolaou, A., Leontsini, D., & Taxildaris, K. (2005). Strength training and detraining effects on muscular strength, anaerobic power, and mobility of inactive older men are intensity dependent. *British Journal of Sports Medicine, 39,* 776-780.

Gutowski, A. E., & Rosene, J. M. (2011). Preseason performance testing battery for men's lacrosse. *Strength & Conditioning Journal, 33(2)*, 16-22.

Lockie, R., Murphy, A., Knight, T., & Janse de Jonge, X. (2011). Factors that differentiate acceleration ability in field sport athletes. *Journal of Strength & Conditioning Research, 25(10)*, 2704-2714.

McCleod, W. D., Hunter, S.C., & Etchison, B. (1983). Performance measurement and percent body fat in the high school athlete. *American Journal of Sports Medicine, 11*, 390-397.

Pistilli, E. E., Ginther, G., & Larsen, J. (2008). Sport-specific strength-training exercises for the sport of lacrosse. *Strength & Conditioning Journal, 30(4), 31-38.*

Romas, I., & Isles, R. (1986). A game analysis of the physiological requirements of attack and midfield state league lacrosse players. *Sports Coach, 10(1)*, 42-45.

Shaver, L. G. (1980). Body composition, endurance capacity and strength of college lacrosse players. *Journal of Sports Medicine & Physical Fitness, 20(2),* 213-20.

Steinhagen, M. R., Meyers, M. C., Erickson, H. H., Noble, L., & Richardson, M. T. (1998). Physiological profile of college club-sport lacrosse athletes. *Journal of Strength and Conditioning Research, 12(4)*, 226-231.

Tanisho, K., & Hirakawa, K. (2009). Training effects on endurance capacity in maximal intermittent exercise: comparison between continuous and interval training. *Journal of Strength and Conditioning Research, 23(8)*, 2405-2410.

Wisloff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine, 38*, 285-288.