Spring 2022

Seasonal Variation in Anthropometric and Performance Variables in American Professional Soccer Players

Hannah Elizabeth Ramirez

SEASONAL VARIATION IN ANTHROPOMETRIC AND PERFORMANCE VARIABLES IN AMERICAN PROFESSIONAL SOCCER PLAYERS

by

HANNAH E. RAMIREZ

(Under the Direction of Stephen Rossi)

ABSTRACT

Preseason is an essential component of sport; it prepares players physiologically for the beginning of the competitive season by allowing for improvements in performance and fitness variables. As the season progresses, the need to maintain an ideal performance state may be difficult due to accumulating training load. The purpose was to determine the seasonal variation of power, agility, and body fat percentage (BF%) via a series of tests throughout the competitive season of American professional soccer players. 23 male United Soccer League (USL) One players underwent a performance battery (akimbo vertical jump (VJ), reactive strength index (RSI), L-Drill and Pro-Agility Shuttle) and 3-site skinfold BF% analysis at three separate times during the course of a 10-month competitive season. All data was recorded by the same trained exercise professionals for the duration of the season. Repeated measures ANOVA analyses (a = 0.05) were used to determine the seasonal variation at the four-separate timepoints (Preseason (P), Start of regular season (S), mid-season (M) and end of season (E)). Post-hoc analyses on significant omnibus findings were analyzed with Bonferroni correction factor. Players who were exempt from testing due to injury are not included in the ANOVA analyses. Four out of the five variables of interest (ACMJ, L-Drill, Pro-Agility Drill and BF%) reported statistically significant effects over the course of the competitive season. No statistically significant interaction was found in RSI between the four timepoints. Based on the results of this study it is recommended that professional soccer teams should repeatedly monitor performance variables of players throughout a competitive season. This insightful information can aid coaches in better understanding how player readiness and how the season can directly affect players.

INDEX WORDS: Performance testing, Body composition, American soccer.

SEASONAL VARIATION IN ANTHROPOMETRIC AND PERFORMANCE VARIABLES IN AMERICAN PROFESSIONAL SOCCER PLAYERS

by

HANNAH E. RAMIREZ

B.S., Georgia Southern University, 2018

A Thesis Submitted to the Graduate Faculty of Georgia Southern University

in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

SEASONAL VARIATION IN ANTHROPOMETRIC AND PERFORMANCE VARIABLES IN AMERICAN PROFESSIONAL SOCCER PLAYERS

by

HANNAH E. RAMIREZ

Major Professor:	Stephen Rossi
Committee:	Samuel Wilson
	Bridget Melton

Electronic Version Approved:
May 2022

DEDICATION

I would like to thank my devoted husband Aaron, for the continuous support throughout my studies, without him this would not have been possible. I would also like to thank my family for their continued support in my education over the years and helping me make all my dreams come true.

ACKNOWLEDGMENTS

- I would like to acknowledge the help of my committee members (Stephen Rossi, Samuel Wilson, and Bridget Melton) for their continued support throughout this process.
- I would also like acknowledge my professors that have assisted me over the years, particularly Greg Ryan for his continued help and support throughout this process.

TABLE OF CONTENTS

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Professional soccer requires athletes to possess high levels of fitness. Monitoring seasonal changes in markers of fitness can provide a valuable insight into the seasonal variation of player readiness to compete and possibly assist in reducing chances of injury. Seasonal performance variation has been primarily explored in the European world of professional soccer; it has been reported that consistent measurement and tracking of performance and fitness variables throughout training and competitive seasons may provide coaches useful information for programming of weekly practice training load (Carling & Orhant, 2010, Clark et al., 2008, Thomas & Reilly, 1979). A competitive soccer season can last upwards of 10 months, depending on the number of competitions and success of the team. This timeline makes it paramount that coaches and training staff ensure that practices are structured to optimize mental and physical fitness, which in turn allows players to sustain optimal performance across an entire season (Metaxas et al., 2006).

Monitoring training load (TL) and fatigue provide information concerning player readiness to compete throughout the season, which can be determined through sport specific testing (lower body power, agility, and body composition). In soccer, lower body power and agility are two main components of the game. Therefore, repeated measurement of these performance variables (e.g. countermovement vertical jump, L-Drill, Pro-Agility testing) provides information to help determine an athlete's readiness to compete and/or train (Turner et al., 2011, Walker et al., 2019). Research shows athletes can experience a reduction in performance during the later stages of the competitive season, which can be linked to fatigue from the accumulation of training load (Kraemer et al., 2004). However, data suggests that soccer players can see an improvement in jump performance over the season, which emphasizes the importance of multiple tests of performance and fitness for monitoring (Caldwell & Peters, 2009). Studies have also evaluated changes in agility performance over a season and as a result of the effects of a soccer season, they have reports significant improvement in agility testing scores (Draijsky et al., 2017, Myelan &

Malatesta, 2009) Therefore, regular and repeated testing is warranted during a competitive season to provide critical information concerning physical readiness to train and compete.

Measurement of body composition is common in professional sports such as soccer, as players are required to possess optimal body composition, as greater adipose tissue can be detrimental to performance (Ostojic, 2003, Stanforth et al., 2014, Walker et al., 2022). Body composition analysis in sports is commonly determined using field-based anthropometry measures such as skinfold measurement to estimate body fat percentage (BF%) and is often employed in team sports (Ackland et al., 2012). As the season progresses body composition improves and typically reaches ideal levels at the end of pre-season conditioning, as a direct result of response to training volume and mode of training (Walker et al., 2022). It may be beneficial to periodically monitor body composition throughout the season to better understand the influence of seasonal training and competition on player readiness to train. Change in an athletes body composition can be an indicator of overtraining or detraining, this emphasizes the need to monitor these changes on a regular basis to implement change to individual/team load if necessary.

Given the current existing literature, a link between performance improvements over the duration of a competitive season can be seen, alongside significant changes in body composition (Caldwell & Peters, 2009, Bishop et al., 2022). However, despite existing literature of seasonal variation existing in elite American soccer and European leagues it has yet to be explored in American professional leagues, particularly with the inclusion of a mid-season and/or off-season time point when determining the competitive season changes in athletes. Therefore, based on existing gaps in the literature, the main purpose of this study seeks to understand if there is a link between the season variation from start of preseason to the end of competitive season through performance testing at four time points through a competitive American professional soccer season.

CHAPTER 2

METHODOLOGY

SUBJECTS

Twenty-three male professional (n = 23) United Soccer League One (USL-1) players were included in the data collection over the course of the competitive season. The team competed in 28 matches (14 home and 14 away) over the 10-month season. All players medically cleared underwent performance testing which included countermovement vertical jump (VJ), reactive strength index (RSI), L-Drill and Pro-Agility Shuttle and three-site skinfold (chest, abdomen and thigh) body fat percentage (BF%) analysis at four separate time points during the 10-months. All players completed a consent form and received an explanation of the risks and benefits of participating in the study. The Institutional Review Board approved the following study. The first data collection was conducted on the first day of preseason (P), then on the start of regular season (S), the mid-season (M) and the final collection at the end of season (E). VJ and RSI were performed on a Just Jump!, (Probotics Inc., Huntsville, AL) mat. All field tests (e.g. agility drills) were set up following the standardized protocol for each test, all tests were set up and recorded by the same experienced testers for all four data collections. Only players who completed all four testing sessions were included in the repeated measure analyses. Players who sustained injuries during the season and players who transferred mid-season, were not included in the analysis due to the incomplete data from all time points.

DESIGN

The following study will be designed as a retrospective cohort study. Four testing sessions were completed at the team's home training ground, a natural outdoor grass field. Prior to each testing battery, players underwent a standard warm up session to ensure they were prepared for testing. The testing battery was designed to assess lower body power, agility, and body composition throughout the competitive season, starting at the beginning of preseason (P), start of regular season (S), the middle of season (M) and finishing at the end of the season (E). All players observed a demonstration of each test. Data collection was performed by the same trained exercise professional technician.

TESTING BATTERY

When determining the sequence of testing it is essential to utilize knowledge of exercise science to ensure the order of tests are guided by this knowledge and participants are given adequate periods of rest between tests, for example there should be at least 2 minutes rest between tests (Haff & Triplett, 2015). The National Strength and Conditioning Association (NSCA) recommends following a specific order when testing to ensure reliability of tests based on the principle that one test should not affect the performance of the following test. The NSCA recommends following the sequence of: non-fatiguing tests (e.g. height, weight, skinfold measurements), agility tests (e.g. T-test, pro-agility test), maximum power and strength tests (e.g. 1RM), sprint tests (e.g. 40m sprint), local muscular endurance (e.g. push ups), fatiguing anaerobic capacity test (e.g. 300-yard shuttle) and aerobic capacity test (e.g. Yo-yo intermittent recovery test) (Haff & Triplett, 2015). Based on NSCA recommendations the testing battery will follow this testing procedure: skinfold measurements, L-drill, Pro-Agility Drill, max VJ and RSI. In order to maintain reliability, all testing sessions will be conducted at the same time of day to ensure fluctuations of physiological response do not occur due to changes in climate (Haff & Triplett, 2015).3

BODY COMPOSITION

Body composition refers to the proportion by weight of fat and lean tissue and can commonly be assessed via skinfold (SKF) measurements (Haff & Triplett, 2015). SKF analysis provides a simple, cost-effective field measurement of body composition and allows individuals body fat % (BF%) to be estimated. SKF assessments were performed by the same expert for each athlete during each time point at the beginning of each testing battery. Due to the high number of athletes being tested, 3-site measurement was decided for this population (e.g. chest, abdomen and thigh). All SKF measures were taken on the right side of the body and conducted by the same expert tester at all four timepoints. In order to determine skinfold thickness a Lange Skinfold Caliper (Cambridge Scientific Industries Inc., Cambridge, Maryland) was used, measuring in millimeters, all three anatomical sites (e.g. chest, abdomen and thigh) were performed twice in rotational order following the direction based on Jackson et al. If the two measurements of SKF deviated more than 2mm at any site a third measurement was performed and then the two closest measurements were averages for that given site (Siri WR, 1961). Once the 3 site measurements had been collected a three-site equation was used to determine each player's body density (Jackson et al., 1980). Body fat percentage was estimated from body density using the Siri equation (%BF = [(4.95/body density) - 4.95)] x 100 (Siri WR, 1961).

PRO-AGILITY DRILL

Agility is a fundamental component of soccer, the pro-agility or also commonly known as the 5-10-5 is widely used by many sports as the gold standard for measuring athletes agility (Papadopoulos et al., 2021). The athlete will begin in the center of the three parallel cones marked out, using a three-point stance (Haff & Triplett, 2015). The athlete begins with an auditory signal and sprints 5 yards to the left cone, ensuring to make contact with the cone with their hand (Haff & Triplett, 2015). Once the athlete has contact with the cone they sprint 10 yards to the far right cone, change direction and sprint back to the center cone (Haff & Triplett, 2015). The time will then be recorded once the test is complete, it is essential that contact is made with the cones, in the event contact is not made the test must be repeated and recorded.

L-DRILL

The L-Drill provides another quick and effective measure of agility which determines how quickly athletes can change direction while accelerating. The L-drill is performed with three cones spaced 5 yards apart from each other in an upside down L configuration (Hoffman, 2020). Athletes will begin the test at the first cone from a 2-point stance, the test begins upon one’s own accord when the athlete sprints forward as fast as possible to the second cone directly in front of the first cone. Once the athlete sprints to the second cone they must make contact with the cone and then reverse in direction and return to the first starting cone (Hoffman, 2020). Upon reaching the starting cone the athlete will make contact with the starting line with the same hand and sprint back towards the second cone, planting their outside leg on the outer second cone and sprint towards the third cone laterally (Hoffman, 2020). The athlete will then circle the third cone and sprint back towards the second cone, cornering the cone and sprinting past the start line of the first cone (Hoffman, 2020). It is important to note that the L-drill is performed with the cones in a left configuration and measured precisely by the same tester using a stopwatch at all four testing timepoints. Each player will be given one trial of the drill, if the player slips or falls during their test they may perform the L-Drill again after adequate rest.

AKIMBO COUNTERMOVEMENT JUMP (ACMJ)

Vertical jump (VJ) testing provides a field test measurement of explosive lower body power; this test can be used as a tool to monitor fatigue. To determine explosive lower body power without influence from the upper body the CMJ was performed from a standing position with hands on the hips (Markovic et al., 2018). All ACMJ max jumps were performed on a Just Jump! mat on top of two pieces of plywood to provide a stable surface on the natural grass training field. All participants will be instructed to complete one maximum VJ, this will be performed after the completion of the regular warm up and agility testing.

REACTIVE STRENGTH INDEX (RSI)

RSI is determined as a measure of explosive strength in a plyometric manner and measures an athletes rapid change from eccentric to concentric contraction by measuring jump height and ground contact time. Reactive strength index will be calculated on a separate trial from ACMJ using a Just Jump! mat. Athletes will be instructed to jump as high and as quickly as possible four times, while maintaining CMJ form, with their hands placed on hips at all times. Athletes will also be instructed upon contact with the ground to jump as high as possible while minimizing contact time on the mat as much as possible

(Haff & Triplett, 2015). RSI is determined by the Just Jump! measuring device by dividing jump height by contact time (Barker et al., 2018).

STATISTICAL ANALYSES

A repeated measures designed ANOVA analysis was used to determine seasonal variation that existed at each of the tested timepoints. All analyses for players who were able to complete all four testing batteries were performed (n = 8) using JASP (Version 0.12; JASP Team, 2020) ($\alpha = 0.05$) at the four-separate timepoints (P), (S), (M) and (E). Post-hoc analyses on significant main effect findings were analyzed with Bonferroni correction factor. Significance was set at $p < 0.05$. Effect size was calculated for all significant post-hoc relationships using Cohen's *d* and evaluated using the following Hopkins scale of magnitude: < 0.1 trivial, 0.1- 0.3 small, 0.3- 0.5 moderate, 0.5 - 0.7 large, 0.7 - 0.9 very large, and > 0.9 distinct (Cohen, 1988).

CHAPTER 3

RESULTS

AKIMBO COUNTERMOVEMENT JUMP (ACMJ)

A statistically significant interaction between the effects of the competitive season on ACMJ n = 10, $F(3, 27) = 12.367$, $p = < 0.001$ was present. The post-hoc analysis identified a significant distinct effect between P (21.04 ± 2.52in) to M (24.21 ± 2.32in, $p = 0.02$, $d = 1.27$) and E (25.17 ± 2.99in, $p = 0.02$, $d = 1.34$). A significant distinct interaction was identified between the S (23.59 ± 2.69in) and E (25.17 ± 2.99in) $p = 0.012$, $d = 1.367$. Figure 2 provides the means and standard deviations for all four timepoints.

BODY COMPOSITION

Following the repeated measure ANOVA there was a statistically significant interaction between the effects of the competitive season on players BF% n = 13, $F(3, 36) = 3.515$, $p = 0.03$. The post-hoc analysis showed that a significant distinct interaction was found between the S (10.07 ± 3.56%) and E (11.14 ± 3.57%) time point, $p = 0.02$, $d = 1.02$. No significant differences existed between other timepoints ($p > 0.05$). Figure 1. provides the means and standard deviations for all the four testing timepoints.

PRO-AGILITY DRILL

A significant difference was found in the Pro-Agility drill n = 8, $F(3, 21) = 12.182$, $p = < 0.01$. The post-hoc analysis identified a significant distinct effect between P (4.74 ± 0.30sec) to S (4.45 ± 0.34sec, $p < 0.01$, $d = 1.88$) and P to M (4.35 ± 0.11sec, $p = 0.02$, $d = 1.64$). Post-hoc analysis revealed a significant distinct effect between M and E (4.65 ± 0.25sec, $p = 0.03$, $d = 1.47$). Figure 3 provides the means and standard deviations for all four timepoints.

L-DRILL

A statistical main effect was found in L-Drill n = 8, $F(3, 21) = 13.946$, $p = < 0.01$. The post-hoc analysis determined that a significant distinct effect was observed between P (7.72 ± 0.42sec) to M (7.15 ± 0.17 sec, $p = 0.01$, $d = 1.85$) and P to E (7.20 ± 0.28, $p < 0.01$, $d = 2.54$). Figure 4 provides the means and standard deviations for all four timepoints.

RSI

Following the repeated measure ANOVA no statistical significance was found in RSI n = 8, $F(3, 27) = 1.750$, $p = 0.19$, between any of the four time points. Figure 5. provides the means and standard deviations for all four timepoints.

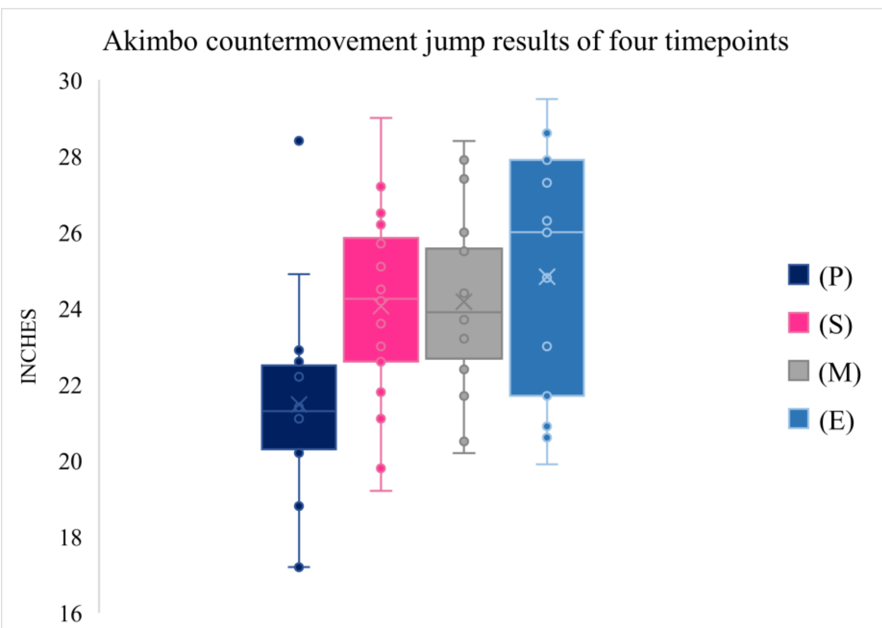

Figure 1.

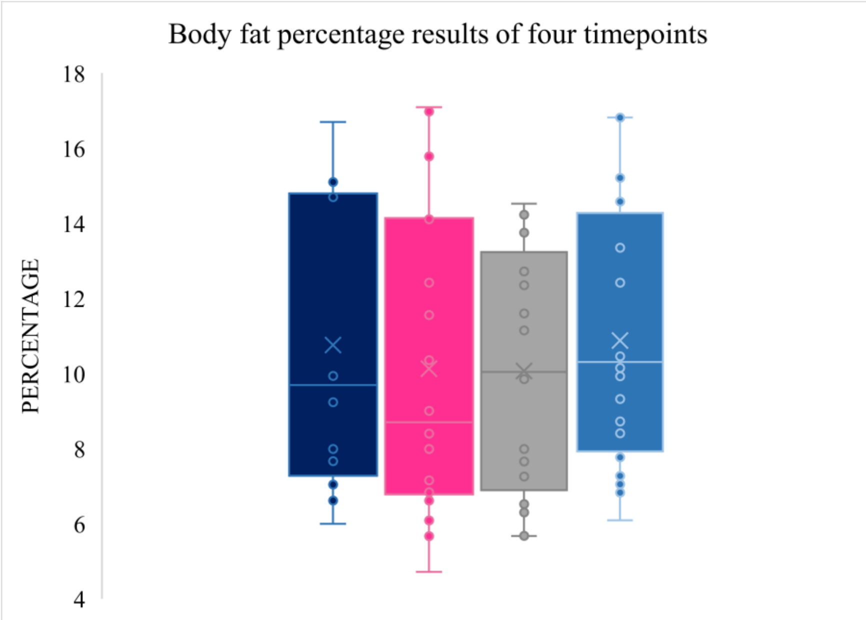

Figure 2.

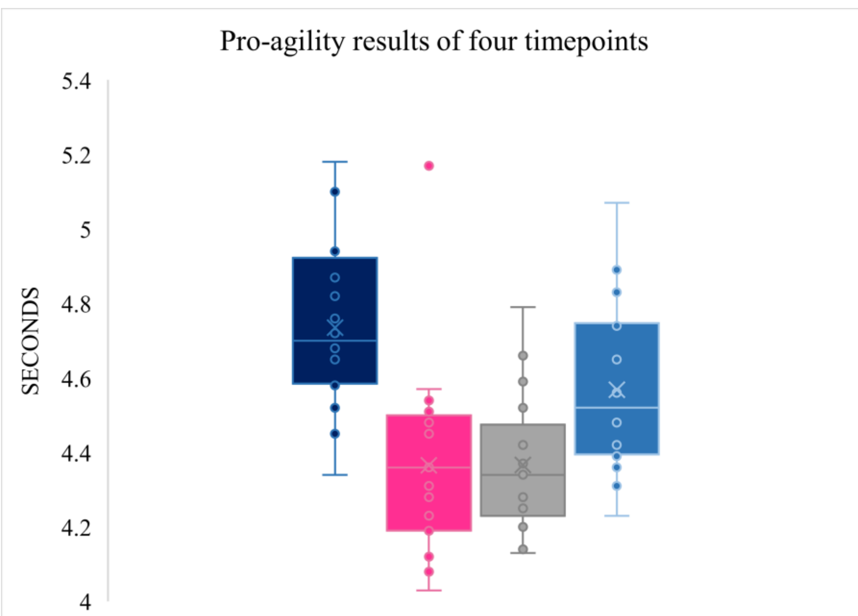

Figure 3.

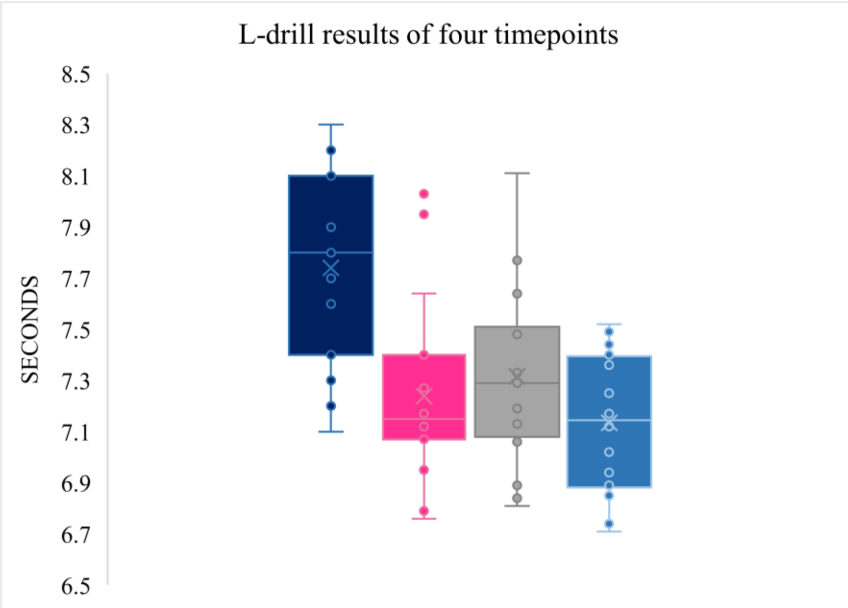

Figure 4.

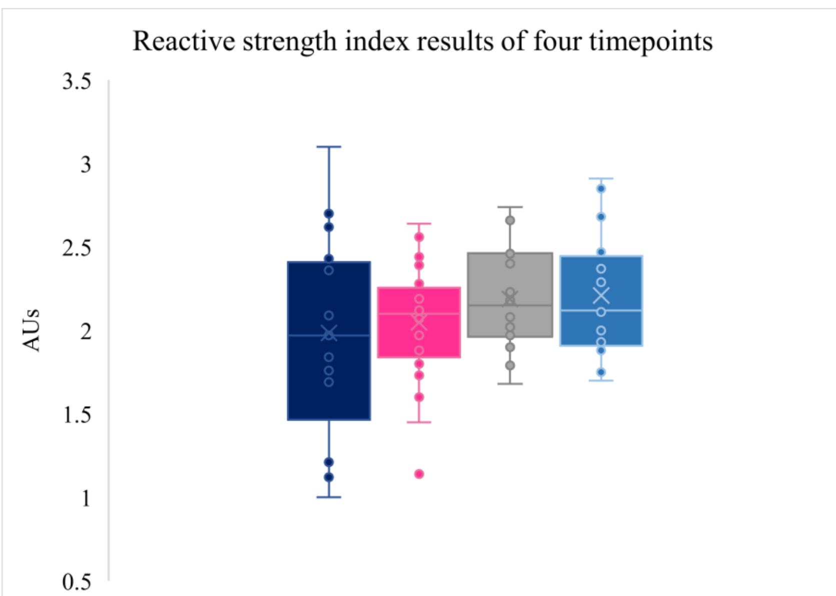

Figure 5.

CHAPTER 4

DISCUSSION

To the best of our knowledge, the current study is the first to investigate seasonal variation in performance and body composition at multiple timepoints in a USL League One competitive soccer season. The present study includes testing at four time points across the season. Repeated measures ANOVA revealed significance in 4 of the 5 variables of interest. The results of the study support the general consensus amongst existing literature, that over the duration of a competitive season performance variables improve significantly (Walker et al., 2022).

Significant interaction was found $F(3, 36) = 3.515$, $p = 0.03$ for body fat percentage (BF%) across the season. The results of the current study reported BF% was lowest at S (10.07 ± 3.56%), following the completion of the preseason period. This aligns with the findings of Walker et al. (2022) who reported BF% to be the lowest following the completion of preseason training due to the training load during this period of the season. We would expect BF% to remain consistent in the maintenance phase (S to E) with minimal fluctuation and potentially increase at end of the season due to the accumulation of load and onset of fatigue (Walker et al. 2022). BF% increased across the last three time points S (10.07 ± 3.56%), M (10.16 ± 3.14%), and E (11.14 ± 3.57%). Walker et al. (2022) reported similar results with BF% decreasing after preseason training (9.3 ± 1.7%) and then slowly increasing throughout the competitive season (10.1 ± 2.0%). Significant interaction was found in our study between S (10.07 ± 3.56%) and E (11.14 ± 3.57%) time point, $p = 0.02$, $d = 1.02$, which aligns with the main findings of existing studies (Caldwell & Peters, 2009, Silverstre et al., 2006, Thomas & Reilly, 1979). While the results from the current study highlight statistical significance it should be noted that this may potentially lack practical significance, as BF% changes were minimal (1%) and could be potentially skewed due to the use of field based measurement. The body composition results in the present study did demonstrate a potential benefit of monitoring body composition to evaluate the effectiveness of training during specific periods of the season.

Based on the results of previous studies we would expect to see improvements in countermovement jump performance across a competitive season (Bishop et al., 2022, Hoffman et al., 2011, Myelan & Malatesta, 2009). Our results are consistent with the results of Caldwell & Peters (2009) which reported significant improvements of CMJ in semi-professional soccer players throughout the season P (54 ± 3.2 cm), S (56 ± 3.7 cm), M (57 ± 3.4 cm) E (57 ± 3.4 cm). These align with the results in our current study, P (21.04 ± 2.52in), S (23.59 ± 2.69in), M (24.21 ± 2.32in) and E (25.17 ± 2.99in) which observed in ACMJ across the competitive season. This is most likely due to the physical improvements of players as a natural response to the accumulation of training and match load. Improvements in CMJ height have also been noted in Premier League academy players throughout the season (Bishop et al., 2022). Statistical significance was not observed in RSI between testing timepoints; these results are similar to the findings of Bishop et al. (2022) who reported that RSI was not sensitive to change over the soccer season. In the present study, RSI and VJ testing were completed using a JustJump! mat, in contrast to utilizing force plates in a laboratory setting. The use of a field based measurement of VJ and RSI may reduce sensitivity to change. However, given the findings reported in previous studies and the current study, it can be suggested that practitioners should implement routine testing of ACMJ to monitor jump performance throughout the competitive season to assess player readiness and preparedness to compete.

Significant interactions were observed for agility and were expected given agility is a critical fitness component of soccer. The ability to change direction was most likely an area of focus during training across the season. Significance was observed in the L-Drill between P (7.72 ± 0.42sec) to M (7.15 ± 0.17 sec, $p = 0.01$, $d = 1.85$) and P to E (7.20 ± 0.28, $p < 0.01$, $d = 2.54$). Similar results were reported following 8 weeks of plyometric training in professional Italian soccer players (Myelan & Malatesta, 2009). Within this study players underwent plyometric drills that included multiple jumps, horizontal and lateral bounding, and footwork on a natural grass field (Myelan & Malatesta, 2009). While our study did not specifically include plyometric training, this type of training was included in pre- and in- season conditioning programs to mimic the explosive bouts incorporated within the game. Significance was also observed in the Pro-Agility drill between P (4.74 ± 0.30sec) to S (4.45 ± 0.34sec, $p < 0.01$, $d = 1.88$) and P to M (4.35 ± 0.11sec, $p = 0.02$, $d = 1.64$). Similar results were observed in Dragijsky et al, (2017) in which reported significant improvements in the agility 505 test from the start of preseason to the end of competitive period 3.6% (Dragijsky et al,. 2017).

CHAPTER 5

CONCLUSION

To summarize, the results of this study examined the impact of USL One competitive season on anthropometric and performance variables throughout various timepoints. Four of the five variables of interest in the testing battery reported statistically significant effects of the season (ACMJ, L-Drill, Pro-Agility Drill and BF%). Future research is still warranted to include and compare more than one USL One team, and test players over more than one year to examine the effects of a competitive season on professional soccer players. We can conclude that continual monitoring of performance throughout a competitive season can provide insightful information into player readiness. This information can help strength and conditioning coaches, soccer coaches in better understanding how the season can directly affect players.

CHAPTER 6

PRACTICAL APPLICATIONS

The data from this study provides insightful information to the limited current knowledge on seasonal variation in American professional soccer players, in particular USL League One. Despite the study providing a valuable snapshot into the seasonal variation of performance, future studies may want to include a more rigorous testing battery consisting of more performance variables that were not used in the current study. The results from the current study provide coaching staff with insight into the physical characteristics of each player at given time points, which can also be compared to the team average. This provides valuable information that can be utilized to monitor player performance to determine if reduction or improvement has been made and whether intervention is necessary.

CHAPTER 7

LIMITATIONS

Within the current study, only one USL League One team data set from a 10-month competitive season was utilized in the current analysis. Given the increasing number of teams being introduced into the USL League and the lack of existing literature within, future studies may warrant the inclusion of more than one team to allow for comparison of players/teams allowing for a larger sample size which can account for the incidence of injury and player transfers. The present study utilized field based measures to determine anthropometric and performance changes, in future studies it may be of interest to include laboratory measurements such as force plate analysis or more in depth body composition analysis such as, Dual-Energy X-ray Absorptiometry (DXA) or Air Displacement Plethysmography (Bod Pod).

REFERENCES

Bishop F, C., Abbott, W., Brashill, C., Loturco, I., Beato, M., & Turner, A. N. (2022). Seasonal variation of physical performance, bilateral deficit and inter-limb asymmetry in elite academy soccer players: which metrics are sensitive to change?. *Journal of Strength and Conditioning Research*.

Caldwell, B. P., & Peters, D. M. (2009). Seasonal variation in physiological fitness of a semiprofessional soccer team. *The Journal of Strength & Conditioning Research*, *23*(5), 1370-1377.

Carling, C., & Orhant, E. (2010). Variation in body composition in professional soccer players: interseasonal and intraseasonal changes and the effects of exposure time and player position. *The Journal of Strength & Conditioning Research*, *24*(5), 1332-1339.

Carling, C., Reilly, T., & Williams, A. M. (2008). *Performance assessment for field sports*. Routledge.

Clark, N. A., Edwards, A. M., Morton, R. H., & Butterly, R. J. (2008). Season-to-season variations of physiological fitness within a squad of professional male soccer players. *Journal of sports science & medicine*, *7*(1), 157.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.) New Jersey: Lawrence Erlbaum

Dragijsky, M., Maly, T., Zahalka, F., Kunzmann, E., & Hank, M. (2017). Seasonal variation of agility, speed and endurance performance in young elite soccer players. *Sports*, *5*(1), 12.

Barker, L. A., Harry, J. R., & Mercer, J. A. (2018). Relationships between countermovement jump ground reaction forces and jump height, reactive strength index, and jump time. *The Journal of Strength & Conditioning Research*, *32*(1), 248-254.

Haff, G. G., & Triplett, N. T. (2015). Essentials of Strength Training and Conditioning (Fourthed.). Human Kinetics.

Hoffman, J. R. (2020). Evaluation of a Reactive Agility Assessment Device in Youth Football Players. *The Journal of Strength & Conditioning Research*, *34*(12), 3311-3315.

Hoffman, J. R., Ratamess, N. A., & Kang, J. (2011). Performance changes during a college playing career in NCAA division III football athletes. *The Journal of Strength & Conditioning Research*, *25*(9), 2351-2357.

Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British journal of nutrition*, *40*(3), 497-504.

Kraemer, W. J., French, D. N., Paxton, N. J., Hakkinen, K., Volek, J. S., Sebastianelli, W. J., & Knuttgen, H. G. (2004). Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters. *Journal of strength and conditioning research*, *18*(1), 121-128.

Magal, M., Smith, R. T., Dyer, J. J., & Hoffman, J. R. (2009). Seasonal variation in physical performance–related variables in male NCAA division III soccer players. *The Journal of Strength & Conditioning Research*, *23*(9), 2555-2559.

Metaxas, T., Sendelides, T., Koutlianos, N., & Mandroukas, K. (2006). Seasonal variation of aerobic performance in soccer players according to positional role. *Journal of Sports Medicine and Physical Fitness*, *46*(4), 520.

Meckel, Y., Doron, O., Eliakim, E., & Eliakim, A. (2018). Seasonal variations in physical fitness and performance indices of elite soccer players. *Sports*, *6*(1), 14.

Meylan, C., & Malatesta, D. (2009). Effects of in-season plyometric training within soccer practice on explosive actions of young players. *The Journal of Strength & Conditioning Research*, *23*(9), 2605-2613.

Ostojic, S. M. (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology*, *6*(3), 11-14.

Papadopoulos, P., Lund, R. J., Ficklin, T. K., & Reed, J. P. (2021). The Role of the Rhythm Step on Pro-Agility Test Performance in Division I Football Players. *Research Quarterly for Exercise and Sport*, *92*(3), 529-536.

Silvestre, R., West, C., Maresh, C. M., & Kraemer, W. J. (2006). Body Composition And Physical Performance In Men's Soccer: A Study Of A National Collegiate Athletic Association Division I Team. *The Journal of Strength & Conditioning Research*, *20*(1), 177-183.

Siri WR. *Techniques for measuring body composition.* Washington D.C: Natural Academy Science; 1961. Body composition from fluid spaces and density; analysis of methods.

Stanforth, P. R., Crim, B. N., Stanforth, D., & Stults-Kolehmainen, M. A. (2014). Body composition changes among female NCAA division 1 athletes across the competitive season and over a multiyear time frame. *The Journal of Strength & Conditioning Research*, *28*(2), 300-307.

Thomas, V., & Reilly, T. (1979). Fitness assessment of English league soccer players through the competitive season. *British Journal of Sports Medicine*, *13*(3), 103-109.

Twomey, J., & Monks, J. (2011). Monopsony and salary suppression: The case of Major League Soccer in the United States. *The American Economist*, *56*(1), 20-28.

Turner, A., Walker, S., Stembridge, M., Coneyworth, P., Reed, G., Birdsey, L., ... & Moody, J. (2011). A testing battery for the assessment of fitness in soccer players. *Strength & Conditioning Journal*, *33*(5), 29-39.

Walker, A., Arent, M., McFadden, B., & Arent, S. (2019). Physical Performance Testing in Soccer. *Elite Soccer Players: Maximizing Performance and Safety*, *137*, 9780429465536-8.

Walker, E. J., Aughey, R. J., McLaughlin, P., & McAinch, A. J. (2022). Seasonal Change in Body Composition and Physique of Team Sport Athletes. *The Journal of Strength & Conditioning Research*, *36*(2), 565-572.

APPENDIX A

LITERATURE REVIEW

Soccer is a sport in which athletes must optimize numerous components of physical fitness, this is primarily due to the high physiological demand throughout the game which is high-intense and both aerobic and anaerobic in nature (Ostojic, 2003, Bishop et al., 2022). Quantifying body composition is an essential component of monitoring athlete performance and is an important health variable (Ackland et al., 2012). Both aerobic and anaerobic fitness have been extensively studied to provide the foundation of fitness in soccer and ultimately directly linked to body composition (Ostojic, 2003). Body composition is an important component of fitness within the sport of soccer, as excess adipose tissue can have a detrimental effect on physical performance as the physical demands placed on the body increase due to increased body mass is continually lifted against gravity (Ostojic, 2003). Ostojic et al. 2003 examined body composition variation in elite male soccer players and reported significant body composition changes at the start and end of the competitive season. The authors reported lower body fat percentage (BF%) was associated with greater performance and a result of training intensity (Ostojic, 2003). As the season progresses it can become more difficult for athletes to maintain ideal body composition and performance due to the accumulation of load, meaning BF% may increase or decrease. In the current study BF% was lowest at the end of the season (9.6 ± 2.5) compared to TP1(11.5 ± 2.1) (Ostojic, 2003). Consequently, this emphasizes the need to monitor seasonal variation of body compositions throughout the season and to prioritize the inclusion of a mid-season data collection point to gain a better representation of seasonal body composition changes.

The study was structured as a repeated-measures longitudinal study over a 12-month period to determine seasonal changes at three timepoints across the season, specifically focusing on where the changes occurred and how they can be compared in the four sports of interest. The overall main findings the authors found in this study were that the substantial changes in body composition were noted from the beginning of preseason to the start of the competitive season, they also found that the significant changes returned towards baseline at the end of competitive season (Walker et al., 2022). Walker et al. conducted a study which examined the seasonal change in body composition of team sport athletes (e.g. Australian football, rugby union, rugby league and soccer). The authors reported body composition peaked following pre-season conditioning, in response to the training type and volume prescribed during this time point (Walker et al., 2022). The authors also reported that based on existing literature as the competitive season progresses it is common to see athletes lean mass decline and fat mass increase, which highlights the significance of monitoring body composition changes (Walker et al., 2022).

Body composition is a key component of an athlete's profile, Walker et al. highlights how significant correlations have been found between body composition and performance variables, for example higher body fat percentage has been linked to lower VJ performance (Walker et al., 2019). Body composition testing can elude physiological response or adaptation to training load, repeated testing of body composition can therefore be utilized by coaches as a fitness marker that can be easily assessed over time. Skinfold assessment is one of the most common field-based methods of body composition, which is determined through assessing the thickness of subcutaneous adipose tissue using calipers to estimate the individual's body density (Walker et at., 2019). When using skinfold measurements to determine body composition, it is recommended to use the same experienced tester when performing the measurements to ensure consistency and reliability of results. The gold-standard laboratory methods of measuring body composition are dual x-ray absorptiometry (DEXA), air-displacement plethysmography (BOD POD) and hydrostatic underwater weighing; these methods are however not as feasible and time efficient as skinfold measurement.

Silverstre et al. (2006) observed the distinct lack of understanding between the relationship of body composition and physical performance in soccer, they examined the relationship between tests of speed, power, and cardiorespiratory fitness (Silvestre et al., 2006). This study categorized players positionally; GK = goalkeepers, BS = backfielders, MI = midfielders and FW = forwards. Interestingly the main findings of this study were that MI were the smallest and lightest, were the slowest in the sprint test and had the shortest jump height in vertical jump testing but did however have the best group values for cardiorespiratory capacity and power production (Silvestre et al., 2006). Significant positive correlations between t total fat speed tests (r = 0.60) and negatively correlated with cardiorespiratory capacity (r = - 0.67) (Silvestre et al., 2006). Overall, as expected total mass, fat mass and percent fat were correlated positively with decreases in performance, in particular speed performance (Silvestre et al., 2006). However, the pivotal observation of the study was the consistency of body type and performance for all player positions, highlighting the success of training programs equally benefiting all players regardless of position (Silvestre et al., 2006).

Many studies have been conducted observing seasonal variations in the English Premier league; male soccer players explored seasonal variation through a 26-test battery at three different time points (Thomas & Reilly, 1979). This study provides insight into the importance in repeatedly tracking fitness measures in soccer players, with the objective of understanding when or if player performance deteriorates, improves, or is maintained throughout a competitive season. The main findings of this study were that significant changes from the start to mid-season were improvements in muscular power, increased heart rate and decreased ankle mobility (Thomas & Reilly, 1979). These findings suggest the importance of monitoring performance in soccer as seasonal changes can be noted as early as the mid-season timepoint, providing insightful information on players to coaches. It was also found that first team players had considerably less body fat and ankle at the end point of competitive season, this suggests that players who had the greatest amount of playing time consequently reported greater changes in body composition as the competitive season progressed (Thomas & Reilly, 1979). Interestingly average weight (kg) of players maintained from the first time point T1 (73.3 ± 7.9) to T2 (73.3 8.3) but on average an increase in body weight was observed at the final time point T3 (74.7 ± 8.7). While the average weight changes are minimal it provides an indication that towards the end of season body composition of players can alter, this could be in response to performance deterioration at the end of a long season (Thomas & Reilly, 1979).

Previous studies have examined the variation of performance over the collegiate season. Magal et al. (2009), conducted a study on male NCAA Division III collegiate soccer players to examine the effect of in-season training and competition on physical performance. Player body composition (BC) and performance variables were measured during the preseason and postseason. The authors reported body mass and percent body fat remained unchanged throughout the competitive season. The results differed from other studies and may be due to differences in training regime, pre-season fitness levels (Magal et al., 2009). When examining changes in aerobic performance, the authors reported VO2 max improved by ~7% at postseason testing (Magal et al., 2009). Pro agility scores were lower at postseason testing, which is different than other variables that improved athe end of the season (Magal et al., 2009).

Performance testing at multiple time points across a season for sports such as soccer, rugby, hockey, and lacrosse can be used to assess preparedness to compete and train along with athletic performance (Carling et al., 2009). Testing and monitoring are an essential component of training and preparation for competition, especially during a competitive season where players must maintain optimal performance. Sports such as soccer require players to possess peak levels of speed, agility, muscular strength, and endurance along with high levels of technical and tactical knowledge (Carling et al., 2009). To monitor and determine individual player status over the course of the season, regular testing should be conducted to yield an objective evaluation of the effectiveness and impact the season and training is having on player performance (Carling et al., 2009).

Strength, power, agility, aerobic and anaerobic capacity testing are key components of field testing. Therefore, regular testing and monitoring of these qualities in players has become the norm in professional soccer and increases the ability for coaches to maximize player performance, reduce injury and identify talent (Walker et al., 2019). One of the most common field tests of power is the vertical jump (VJ) test, or countermovement jump (CMJ) (Bishop et al., 2022, Caldwell & Peters, 2009, Walker et al., 2019). The VJ test is a feasible measure of lower body power and fatigue that can be conducted throughout the season (Walker et al., 2019). Soccer consists of multiple short, fast paced changes in direction, which is commonly referred to as agility. Agility is the ability to maintain control of the body through acceleration, deceleration and change in direction, this is an essential physical component that is continually used in the game of soccer (Walker et al., 2019). Being able to quantify and monitor agility and lower body power across a season will allow coaches to assess seasonal changes in performance to adjust in training to reach the best possible performance.

Prior to athletes beginning a strength and conditioning program or a competitive season it is important to assess an athlete's fitness level and preparedness to begin training and competing and this assessment is beneficial if carried throughout training and the competitive season (Turner et al., 2011). This allows for coaches to identify and assess areas of strengths and weaknesses that need addressing, particularly when it comes to player selection for games and identifying performance decline. The recommendation for a test battery for fitness in soccer players consists of anthropometric measures, squat jump, counter movement jump, reactive strength, 1 repetition maximum (1RM), Pro-Agility, linear speed and Yo-Yo intermittent recovery test (Turner et al., 2011). When designing a performance testing protocol, it is suggested to follow recommendations for test order and rest between tests (Turner et al., 2011).

Due to the nature of soccer being extremely high in intensity, requiring players to maintain optimal physical fitness, it is paramount that coaches monitor metrics continually over the season to determine which variables are sensitive to change (Bishop et al., 2022). The following study explored 19 under-20 Premier Leagues academy players over a competitive season, testing at three separate timepoints (Bishop et al., 2022). The players underwent a testing battery that consisted of bilateral CMJ, SLCMJ, sprint testing, and agility testing. The authors reported that jump height of the CMJ and linear speed improvements were the only metric to show significant increases over the season (Bishop et al., 2022). Not only does repeated testing provide insightful information of all players at a given time point, but it also allows for coaches to monitor and compare physical fitness such as agility, speed and power across a competitive season and compare to team or standardized averages.

Furthermore, a similar study was conducted on semi-professional English soccer players (Caldwell & Peters, 2009). Participants underwent a battery of fitness assessment at 5 timepoints over a 12-month period, testing included aerobic fitness, vertical jump, sprint speed, agility, and BF%, and flexibility (Caldwell & Peters, 2009). This study was uniquely structured due to the inclusion of the full season and the effect the off-season period can have over the 12-month cycle (Caldwell & Peters, 2009). The authors reported that the "off season" time resulted in the greatest reduction in sport-specific fitness for players, including deconditioning in all fitness variables (Caldwell & Peters, 2009. Caldwell & Peters found that all fitness components showed significant improvements from the "off season" with BF% significantly decreasing post preseason as a direct result of high levels of aerobic, anaerobic training intensities. This combined with other reported findings emphasizes the importance of the preseason period to seek improvements of performance (Caldwell & Peters, 2009, Magal et al., 2009, Walker et al., 2022).

In conclusion, despite the great volume of studies examining soccer, longitudinal data collection of seasonal variation of physical components is limited (Bishop et al., 2022). There is limited current research examining seasonal variation in performance variables in American professional soccer, supporting literature that highlights the emphasis to continually explore the monitoring of performance throughout the season (Bishop et al., 2022, Caldwell & Peters, 2009).

Appendix References

Ackland, T. R., Lohman, T. G., Sundgot-Borgen, J., Maughan, R. J., Meyer, N. L., Stewart, A. D., & Müller, W. (2012). Current status of body composition assessment in sport. *Sports Medicine*, *42*(3), 227-249.

Bishop, C., Abbott, W., Brashill, C., Loturco, I., Beato, M., & Turner, A. N. (2022). Seasonal variation of physical performance, bilateral deficit and inter-limb asymmetry in elite academy soccer players: which metrics are sensitive to change?. *Journal of Strength and Conditioning Research*.

Caldwell, B. P., & Peters, D. M. (2009). Seasonal variation in physiological fitness of a semiprofessional soccer team. *The Journal of Strength & Conditioning Research*, *23*(5), 1370-1377.

Magal, M., Smith, R. T., Dyer, J. J., & Hoffman, J. R. (2009). Seasonal variation in physical performance–related variables in male NCAA division III soccer players. *The Journal of Strength & Conditioning Research*, *23*(9), 2555-2559.

Ostojic, S. M. (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology*, *6*(3), 11-14.

Silvestre, R., West, C., Maresh, C. M., & Kraemer, W. J. (2006). Body Composition And Physical Performance In Men's Soccer: A Study Of A National Collegiate Athletic Association Division I Team. *The Journal of Strength & Conditioning Research*, *20*(1), 177-183.

Thomas, V., & Reilly, T. (1979). Fitness assessment of English league soccer players through the competitive season. *British Journal of Sports Medicine*, *13*(3), 103-109.

Turner, A., Walker, S., Stembridge, M., Coneyworth, P., Reed, G., Birdsey, L., ... & Moody, J. (2011). A testing battery for the assessment of fitness in soccer players. *Strength &Conditioning Journal*, *33*(5), 29-39.

Walker, A., Arent, M., McFadden, B., & Arent, S. (2019). Physical Performance Testing in Soccer. *Elite Soccer Players: Maximizing Performance and Safety*, *13* 9780429465536-8.

Walker, E. J., Aughey, R. J., McLaughlin, P., & McAinch, A. J. (2022). Seasonal Change in Body Composition and Physique of Team Sport Athletes. *The Journal of Strength & Conditioning Research*, *36*(2), 565-572.