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FACTORS INFLUENCING HARD RUNNING DISTANCES IN NCAA DIVISION I FEMALE SOCCER PLAYERS

Isaac A. Sam

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By

Isaac A. Sam

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The members of the Committee appointed to examine
the Thesis _____ of Isaac A. Sam
find it satisfactory and recommend that it be accepted.

DocuSigned by:
Hyung Suk Yang
27D1A8484CCE489...

Chairperson

DocuSigned by:
Amanda A. Anderson
EE98592E7CAB48B...

DocuSigned by:
Emma L. Johnson
DF7A1426A1824DE...

ABSTRACT

As the total distances covered in soccer games have remained relatively constant, the hard running distances covered by players have shown varying changes due to the higher physical demands and dynamics of team running performances. Although factors affecting the total distances covered in a match are multifactorial, no study has specifically examined match performance indicators (MPI) that impact hard running distances (HRD). Consequently, the purpose of this study was to better understand how MPI (hard running efforts, turnovers, minutes played, duels won, duels lost, and pass completions) are associated with HRDs and to investigate how each variable contributes to HRDs using multiple regression analysis. The study included a sample of 21 female Division I soccer players aged between 18 and 22 (Mean ± Standard Deviation = 20 ± 1.32 years), all of whom were outfield players: center backs (n = 5), defensive midfielders (n = 4), outside midfielders (n = 5), center-attacking midfielders (n = 4), and center forwards (n = 3). Overall, all match performance indicators were positively associated ($0.639 \leq r \leq 0.992$) with hard running distances; yet hard running efforts (HRE) showed the strongest relationship with HRDs ($r = 0.992$). The regression models indicated that all variables contributed to hard running distances. Particularly, hard running effort (HRE) had the most significant impact ($p < 0.001$), implying its dominant influence on HRDs compared to other variables. These findings may play a pivotal role in supporting coaches and trainers to better understand the influence of MPIs on hard running distances. The models developed could help predict a player's workload concerning HRDs.

Keywords: hard running distances, hard running efforts, match performance indicators, fatigue, women's soccer

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CHAPTER I: INTRODUCTION

The running performances of soccer teams can represent an important determinant of a team's success (Goranović et al., 2022). Players covering distances with intense running efforts frequently surpass their opponents in work rate (Rivilla-García et al., 2019), setting high pressing standards or fatiguing their rivals, ultimately improving their prospects of winning matches. On average, outfield players normally cover a total distance ranging from approximately 9978 to 12070 meters, achieved through a combination of walking and running at various intensities (Lorenzo-Martinez et al., 2021). Despite the overall distances players cover in a match tending to stay relatively stable, there is a noticeable increase in hard runs, which include intense sprints and high-speed activities (Bush et al., 2015), due to increases in the physical demands of soccer (Hostrup & Bangsbo, 2023). These hard running distances are completed in both continuous and intermittent intervals, yet a universally agreed-upon definition for what constitutes hard running distances remains ambiguous (Atakan et al., 2021). Generally, hard runs entail a challenging level of running effort that pushes the body, but the threshold is relative to the individual fitness levels of players.

Although hard runs can be a determinant of a team's success, performing them under unsuitable conditions can adversely affect a player and, consequently, the team's chances of winning. Firstly, players undergoing a rapid escalation in their regular training loads involving hard runs, exceeding their acute chronic work ratio (ACWR) by 1.5 may elevate their vulnerability to soft tissue injuries (Malone et al., 2018). ACWR is the ratio of one week's workload (acute workload) to a 4-week average acute workload (chronic workload). Secondly, hard running distances have been linked to greater fatigue levels compared to lower running intensities in soccer (Marqués-Jiménez et al., 2017). Consequently, less fit players engage in fewer hard runs during a match because they experience a quicker onset of fatigue which impacts both technical and presumably tactical performance (Beato, Drust, & Iacono, 2021; Hostrup & Bangsbo, 2023). Comparatively, lower-tier teams and amateur players tend to undertake fewer hard runs compared to their higher-tier and professional counterparts (Miñano-Espin et al., 2017). The observation suggests that although the extent of hard runs in a match is just one factor in deciding a team's success, higher-tier teams are more likely to succeed against lower-tier teams. This likelihood of success of higher-tier teams may be due to lower-tier teams being more prone to rapid fatigue, resulting in decreased running performance, which could affect their ability to win games.

Examining the intricate relationship between various factors and their influence on the running performance of soccer teams has become a critical focus for researchers in the field. Overall, factors such as fatigue (physical and mental), contextual conditions (competitive standards, opposition, etc.), tactical systems, technical abilities, and various other conditions can influence match running performance (Carling et al., 2016; Lorenzo-Martinez et al., 2021; Paul, Bradley, & Nassis, 2015). A variable that has gained much attention is ball possession; it is the ratio of time one team holds the ball while playing a game (García-Calvo et al., 2022). Although ball possession has proven to be a superior indicator of performance because of the success of teams like Manchester City, FC Bayer Munich, FC Barcelona, and the Spanish and German national teams (Casal et al., 2019), its importance is gradually diminishing because current findings show that teams with inferior ball possession rates have had significant success at winning games (Wang et al., 2022). Despite the decline in superiority with regard to ball possession as a performance indicator, it still holds monumental importance in a soccer game; teams with higher possession impose greater physiological and psychological stress on the opponents making them more susceptible to defeat (Wang et al., 2022). Greater ball possession has an inverse relationship with distances covered at various speed thresholds (García-Calvo et al., 2022). Teams with higher ball possession cover less total distance than their opponents, which makes them less susceptible to fatigue and hence increases their odds of better performance.

Furthermore, individual variability and variability between halves contribute to differences in both hard running distance and the total distance covered by players in a match. This variability has been linked to individuals' aerobic capacity and their regulatory efforts to mitigate the risk of fatigue (Carling et al., 2016). For instance, players may consciously engage in short sprints, regulate their running efforts, and conserve energy to sustain the anticipated performance levels throughout a match as developing fatigue can be detrimental to running, tactical and technical performance. Also, players may experience a decline in running performances in the second half compared to their first half (Paul, Bradley, & Nassis, 2015).

Despite numerous studies that have investigated variables such as ball possession (García-Calvo et al., 2022), competition standards, fatigue level (Mohr, Krustrup, & Bangsbo, 2003) , and various other contextual factors (Carling et al., 2016; Linke et al., 2018) that affect running performances, to the author's knowledge, there has been no specific investigation of how match performance indicators (MPIs) are associated with hard running distances. As evidenced earlier, hard running distances serve as determinants for high performance among top-class players, contribute to fatigue, and can stimulate injuries in soccer.

Research on the physical demands of soccer in general has been extensive; yet, there has been relatively limited focus specifically on women's soccer even though disparities in performances between genders are acknowledged in physically demanding sports (Pedersen, Aksdal, & Stalsberg, 2019; Sandbakk, Solli, & Holmberg, 2018; Thibault et al., 2010). Hence, this study aims to bridge this gap by investigating the relationship between match performance indicators (hard running effort, player turnover, pass completion, minutes played, duels won, and duels lost) and hard running distances, and ascertain how each variable contributes to HRDs on an NCAA DI women's soccer team.

CHAPTER II: METHODS

Participants

All the participants included in the study were female players from a Division I collegiate soccer program, comprising of 21 individuals aged between 18 and 22. The included participants were only outfield players: center backs (n = 5), defensive midfielders (n = 4), outside midfielders (n = 5), center-attacking midfielders (n = 4), and center forwards (n = 3). Those participants who sustained injuries or had incomplete data were excluded from the sample pertaining to the specific game in which the incident occurred.

Data Collection

All data used in the study were acquired retrospectively. Hard running distances and hard running efforts of players were recorded using a FIFA-approved Sports Performance Tracking Global Positioning System (SPT GPS, Melbourne, Australia). Data on HRDs and HREs were then collected on, Gametraka, a data storage platform. Turnovers, pass completions, minutes played, duels won, and duels lost were obtained from Wyscout, (Genoa, Italy), a software used for video analysis, scouting services, and generating soccer-related data on player performance statistics. To protect Personal Identifiable Information (PII), a manual deidentification process was performed, replacing PII with unique identifiers and alphanumeric codes. Given the non-experimental nature of the research, the Institutional Review Board (IRB) did not require participants to sign an informed consent form; therefore, none of the participants in the study signed an informed consent form.

Procedures

Before each game, players were equipped with a 27-gram GPS device with a sampling rate of 10 Hz, placed in a vest on the upper back between the scapulae. The players wore the GPS devices before warmups and returned the device immediately after each game. The data from Wyscout and GPS analyses were combined to create a cumulative dataset, and Excel was utilized to sum each player variable to cumulative data points for each variable.

Statistical Analysis

Jamovi (version 2.3.21) was used to perform statistical analysis on the cumulative dataset. Descriptive statistics were computed, and the normality of all data was checked using skewness, kurtosis, and the Shapiro-Wilk test. All predictor variables were examined to explore the relationships with hard running distances. Pearson's correlation coefficient (r) was used to interpret the strength and direction of relationships based on the magnitude: low ($0.3 < r \leq 0.5$), moderate ($0.5 < r \leq 0.7$), high ($0.7 < r \leq 0.9$), and very high ($r > 0.9$) (Mukaka, 2012). A multiple regression analysis was used to estimate the relative contributions of predictor variables (hard running efforts, turnovers, minutes played, duels won, duels lost, and pass completions) on hard running distances. Predictors with a variance inflation factor (VIF) greater than 10 were removed from the analysis to address multicollinearity on the model, and a second multiple regression analysis was performed using only variables with a VIF less than 10 (hard running efforts, turnovers, duels lost, and pass completion). The assumption of linearity between predictors and HRD was confirmed using scatterplot examinations, indicating no apparent nonlinear patterns. Additionally, the Durbin-Watson statistic was computed (2.70), suggesting no substantial linear autocorrelation in residuals. The homoscedasticity was accessed with the residual plot which showed a somewhat random scattering of dots around zero, suggesting equal variances of variables. The significance level (alpha) was set at 0.05.

Table 1. Operational Definitions for Key Variables

Variables	**Definition**
Hard running distances (HRD)	any distances covered while running at a speed exceeding 4.5 m/s. This metric was determined by the preset specifications of the GPS device used to track and record hard running distances.
Hard running efforts (HRE)	an athlete must maintain the hard-running threshold of 4.5 m/s for longer than 1 second to register a hard-running effort.
Turnovers (T)	the loss of possession of the ball by a player
Minutes played (MP)	the amount of time an athlete participates in games
Duel won (DW)	a situation where a player successfully prevails in a one-on-one challenge against an opponent
Duels lost (DL)	a situation where a player is unsuccessful in a one-on-one challenge against an opponent
Pass completions (PC)	a situation where a player passes the ball to another player, where the receiving player gains control of the ball without it being intercepted by an opponent.

CHAPTER III: RESULTS

Part 1 - Normality of variables

Based on the measures of kurtosis, skewness, and Shapiro-Wilk tests, all variables (HRD, HRE T, MP, DW, and DL) demonstrated characteristics of a normal distribution except for PC (Table 2).

Part 2 - Correlational Study

All match performance indicator variables showed positive correlations with hard running distances. Specifically, hard running efforts showed a very high association ($r = 0.992$, $p < 0.001$), followed by duels won ($r = 0.797$, $p < 0.001$), duels lost ($r = 0.787$, $p < 0.001$), pass completion ($\rho = 0.776$, $p < 0.001$), minutes played ($r = 0.742$, $p < 0.001$), and turnovers ($r = 0.639$, $p = 0.002$).

Table 2. Descriptive Statistics on Variables

Variables	**Mean ± Standard Deviation**	**Kurtosis**	**Skewness**	**Shapiro-Wilk *p* value**
Hard running distances (m)	2743±1440	-1.03	0.15	0.480
Hard running efforts	135±73.1	-1.07	0.12	0.348
Turnovers	47.1±26.7	-0.60	0.47	0.531
Minutes played (min)	421±233	-1.47	0.07	0.071
Duels won	58.7±32.2	-0.95	0.29	0.400
Duels lost	53.8±34.2	-0.17	0.73	0.095
Pass completion	91.5±54.6	-1.26	0.45	0.023

Table 3. Predictor Relationships with Hard Running Distances

Hard Running Distances vs. Predictors	**R**	**R^2**	***p* value**
Hard running effort	0.992	0.985	<0.001*
Turnovers	0.639	0.639	<0.002*
Minutes played	0.742	0.551	<0.001*
Duel won	0.797	0.634	<0.001*
Duel lost	0.787	0.620	<0.001*

Hard Running Distances vs. Predictors	**R**	**R^2**	***p* value**
Pass completion#	0.776	0.568	<0.001*

* $p < .05$, N = 21, #denotes that Pass completion failed the normality assumption and hence, Spearman's rho (ρ) was used to determine the relationship between HRD and PC

Part 3A - Multiple Regression Analysis (Six Predictor Variables)

The result of the multiple regression analysis on hard running distances (HDR) and six predictor variables in Model A, included hard running effort (HRE), turnovers (T), minutes played (MP), duels won (DW), duels lost (DL), and pass completions (PC) revealed statistically significant relationship ($F(6, 14) = 171$, $p < 0.001$). This indicates that the predictors jointly explained a significant portion of the variance in hard running distances. The model explained 98.7% of the variance in hard running distances ($R^2 = 0.987$). The equation is HRD = 128.681 + 0.0245(MP) + 1.0493(HRE) + 0.0176(PC) - 0.0153(T) - 0.00775(DW) - 0.0188(DL). All predictor variables, except for HRE ($p < 0.001$), showed insignificant *p* values.

Part 3B - Multiple Regression Analysis (Predictor Variables with VIF < 10)

Four predictor variables HRE, T, DL, and PC in Model B revealed a statistically significant relationship with HRDs ($F(4, 16) = 285$, $p < 0.001$) which indicated that the predictors jointly explained a significant portion of the variance in hard running distances. The model explained 98.6% of the variance in hard running distances ($R^2 = 0.986$). The equation is HRD = 125.123 + 1.0442(HRE) + 0.0236(PC) – 0.0326(T) – 0.0597(DL). All predictor variables, except for HRE ($p < 0.001$), showed insignificant *p* values (Tables 4 and 5).

Table 4. Regression Coefficients of 6 Predictor Influences on Hard Running Distances

Predictors	**Estimate**	**SE**	***t***	***p***	**Stand. Estimate (β)**	**VIF**	**Tolerance**
Intercept	128.68	99.53	1.29	0.217			
Hard Running Efforts (m)	20.69	1.15	17.96	< 0.001	1.05	3.54	0.28
Turnovers	-0.82	4.14	-0.20	0.845	-0.02	6.09	0.16
Minutes Played (min)	0.15	0.78	0.20	0.848	0.03	16.41	0.06
Duels Won	-3.47	5.83	-0.60	0.562	-0.08	17.65	0.06
Duels Lost	-0.79	3.88	-0.20	0.841	-0.02	8.79	0.11
Pass completions	0.46	2.31	0.20	0.844	0.02	7.94	0.13

Table 5. Regression Coefficients of 4 Predictor Influences on Hard Running Distances

Predictor	**Estimate**	**SE**	***t***	***p***	**Stand. Estimate (β)**	**VIF**	**Tolerance**
Intercept	125.12	93.87	1.33	0.201			
Hard Running Efforts	20.59	1.08	19.08	< 0.001	1.04	3.46	0.29
Turnovers	-1.76	2.86	-0.62	0.547	-0.03	3.23	0.31
Duels Lost	-2.52	2.39	-1.05	0.308	-0.06	3.72	0.27
Pass completions	0.62	1.79	0.35	0.733	0.02	5.35	0.19

CHAPTER IV: DISCUSSION

The purpose of the study was to investigate the relationship between match performance indicators and hard running distances and ascertain how each variable contributes to hard running distances in an NCAA DI women's soccer team. The correlational findings revealed that all performance indicators; hard running effort (HRE), turnover (T), minutes played (MP), duels won (DW), duels lost (DL), and pass completion (PC) have a positive correlation with hard running distances. The results of both multiple regressions showed that the overall model was statistically significant suggesting that all predictors contributed to hard running distances.

In the initial analysis involving all six predictors, Model A accounted for approximately 98.7% of the variance in hard running distances. Notably, HREs demonstrated a significant impact on HRDs; yet, T, MP, DW, DL, and PC had their p values greater than 0.05. After removing MP and DW from the analysis due to their VIF values exceeding 10, the subsequent multiple regression analysis in Model B accounted for approximately 98.6% of the variance in hard running distances. This finding suggests that the VIF values of MP and DW do not substantially affect the initial regression model, as MP and DW may not necessarily impact the interpretation of each predictor's effect on HRD. Notably, among the predictors (HRE, T, DL, and PC) in Model B, only HRE showed a significant influence on hard running distances.

Among all the match performance indicators, HRE showed the greatest association with HRDs. This relationship and statistical significance ($r = 0.992$, $p < 0.001$) found between HRE and HRD show a very high association. Currently, to the best of the author's knowledge, this is the only study that supports the association in the correlational analysis of the study. Other researchers have concentrated on the technical, tactical, and positional factors that influence hard running distances. This high degree of linear relationship between HRE and HRD can suggest predictability to enable coaches to estimate one variable if they have knowledge of the other variable. For example, coaches can predict the amount of HRE players exert in a match if they know the amount of HRD players have to cover to outwork their opponents.

In the current study, technical actions (DW, DL, and PC) resulted in a positive correlation with HRD. Existing literature has reported that technical actions (PC) resulted in a statistically significant relationship ($r = 0.70$) with hard running distances (Alexander, 2014), which is similar to the findings of the current study because they showed a moderately high correlation ($0.639 \leq r \leq 0.797$). This finding could translate that with an increase in hard running distances, technical actions (PC, DW) may increase. Fit players are more likely to excel in technical actions like completing more passes and winning more duels compared to less fit players. An increase in HRD may cause faster fatigue onset in less fit players, which may negatively affect their pass completion rates and dueling success; hence, increasing their losses in duels.

The association between HRD and MP ($r = 0.742$, $p < 0.001$) shows a positive relationship. This moderate correlation suggests that as a player's playing minutes increase, so do the player's hard running distances. Existing literature accounts for the relationship between minutes played and workload among starters versus nonstarters, and it was evident that starters had greater cumulative workload, primarily because of the playing time factor (Casamichana et al., 2022). This finding supports the findings in the current study, as MP is directly proportional to hard running distances. Coaches and trainers should closely monitor the work rate of both starting players and nonstarters. Despite trivial differences in pass completion percentages, substitutes demonstrate a higher rate of HRD at 12.4 ± 5.3 m/min compared to players who complete the entire game (9.8 ± 3.2 m/min) or those substituted out during the game (11.3 ± 3.2 m/min) (Furtado Mesa et al., 2023). Understanding this relationship among different players can alter training approaches to help players develop a better physiological response which can increase their performances.

In the current investigation, the relationship between HRD and T shows ($r = 0.639$, $p < 0.002$) a moderately high correlation. Another research finding draws similar conclusions when analyzing distances covered by teams from different leagues – a US first division team (considered upper class) versus teams from Danish and Swedish leagues (considered lower class) (Mohr et al., 2008). Although there were no substantial differences observed between player classes, the greater distances covered by lower-class players might stem from their comparatively lower skill levels increasing in their number of turnovers (Alexander, 2014). This increase in distances covered and turnovers is linked to players engaging in recovery and defensive runs which supports the association between HRD and T; an increase in turnovers can contribute to higher hard running distances among players. Coaches and analysts can use this correlation to devise game strategies to minimize turnovers. For instance, a coach might consider changing tactics or making substitutions strategically to manage player fatigue and reduce turnovers during critical phases of the game.

Both multiple regression analyses performed in the study increased the understanding of the relative influence of each MPI on HRDs. Both models, even after removing predictor variables with VIF greater than 10, exhibited statistical significance. Model A showed that at least one of the predictor variables had a significant impact on HRD. The combination of the effects of all the variables in models remains influential in explaining the variance in HRD. The significance of this finding implies that although various performance indicators may contribute to HRD, HRE remains the primary contributor to HRDs covered in a soccer match. This insight is important for coaches and trainers involved in player assessment and training as it emphasizes the need for specialized training programs focusing on improving players' capacity for hard running efforts during matches. Coaches should monitor and manage player exertion levels in training and matches as it can be essential to optimizing performance and minimizing fatigue and injuries related to HRDs. A practical application of this insight includes the development of tailored training regimens, effective management of player exertions, and making well-informed strategic decisions. Eventually, these efforts aim to improve player performance.

Although this study provides important and practical implications for coaches on relationships between MPIs and HRDs, limitations in the study should be recognized. The focus of the analysis was on just one NCAA DI team. There was variability in the playing times of participants (421 ± 233 minutes), and a limited number of games were analyzed. In increasing external validity, future researchers should consider using sample data from different leagues and multiple teams and specifically, investigate teams with different styles of play (possession-play versus direct-play characterized teams) as match performance indicators may have different associations with hard running distances. Researchers should also standardize the performance time of players and increase the number of games analyzed. Future researchers should continue to investigate the relationship between the match performance indicators and hard running distances to validate or contradict the current findings.

Conclusion

This current research represents the first attempt to investigate the relationship between MPIs and HRDs and ascertain how each variable contributes to HRDs. Based on the results of the study, hard running efforts, turnovers, minutes played, duels won, duels lost, and pass completions all influence the amount of hard running distances covered in the game; yet, among these variables, hard running efforts have the greatest relationship on the amount of hard running distances covered in a game. Coaches and trainers should consider developing training programs tailored to increase the hard running efforts of players which can enhance team performances. Furthermore, the understanding of the influences of MPIs on HRDs can guide workload demands on subsequent training periods and future matches which ultimately helps to reduce the risk of injuries while maintaining or increasing peak performance: odds that can favor a team's likelihood of success. Coaches can optimize their game plans by making informed decisions about tactical adjustments, formations, and player substitutions with the goal of maximizing efficiency while minimizing player fatigue.

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