Evolution of World Cup soccer final games 1966–2010: Game structure, speed and play patterns

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Evolution of World Cup soccer final games 1966–2010: Game structure, speed and play patterns

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ABSTRACT

Objectives: There are relatively few performance analysis studies on field sports investigating how they evolve from a structural or tactical viewpoint. Field sports like soccer involve complex, non-linear dynamical systems yet consistent patterns of play are recognisable over time and among different sports. This study on soccer trends helps build a framework of potential causative mechanisms for these patterns.
Design: Retrospective correlational study.
Methods: Broadcast footage of World Cup finals between 1966 and 2010 was used to assess patterns of play and stop periods, type and duration of game stoppages, ball speed, player density (congestion) and passing rates. This involved computer-based ball tracking and other notational analyses. These results were analysed using linear regression to track changes across time.
Results: Almost every variable assessed changed significantly over time. Play duration decreased while stoppage duration increased, both affecting the work: recovery ratios. Ball (game) speed increased by 15% over the 44-year period. Play structure changed towards a higher player density with a 35% greater passing rate.
Conclusions: Increases in soccer ball speed and player density show similarities with other field sports and suggest common evolutionary pressures may be driving play structures. The increased intensity of play is paralleled by longer stoppage breaks which allow greater player recovery and subsequently more intense play. Defensive strategies dominate over time as demonstrated by increased player density and congestion. The long-term pattern formations demonstrate successful coordinated states within team structures are predictable and may have universal causative mechanisms.

1. Introduction

Association Football (soccer) is the most popular sport in the world, played in almost every country and by an estimated 265 million participants. On the international stage, the best players represent their nations every four years at the FIFA World Cup, the largest single-event sporting competition (http://www.fifa.com). Qualification for the 2010 World Cup tournament held in South Africa, for example, involved 204 countries competing for a position in the final 32 teams.

Soccer, like all field sports, is composed of a series of play periods that are randomly interspersed with stop periods, typically where the referee has called an infringement or the ball is out of the playing field. Soccer is non-continuous and the energy demands involve a variety of intense anaerobic movements interspersed with more low-intensity aerobic activities.[1] Elite players require a large range of motor skills, as well as the need for rapid information processing and decision-making as play moves between attacking and defending actions. These physical and motor skill attributes occur within a tactical framework encompassing set plays, playing styles and team strategies, and that may need to be modified depending on the opposition, environmental conditions and score line.

There is a great deal of scientific enquiry into how these various elements of the game interact and how performance can be enhanced using tools such as notational, motion and performance analyses to link to game outcomes.[2] As technologies have improved these methods have moved from being essentially descriptive, for example, quantifying player movement distances and speed breakdowns within games, to helping coaches recall important information from games, and in optimising player conditioning through specificity of training drills.[2,3] More explanatory applications have described relationships between team pattern formations and their link to match results,[4] and with underlying theoretical explanations of performance.[4]

Glazier[5] argues that performance analysis is a science subdiscipline working from the intra-individual to the inter-individual level using biomechanics and notational analysis to examine emergent pattern formations and their relationships with performance

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outcomes. Performance analysis research typically operates over a relatively small time frame when assessing interpersonal and spatial interactions on the playing field, and their association with success and failure. This may vary from a few seconds, such as the player velocity and positioning in discrete plays to passing sequences, and even entire games such as assessing variability in high speed movements from match to match.[4,6] We extend this idea to a broader level of field sport research. This incorporates game and seasonal comparisons of patterns of play that often change over a longer period of time and add insight into how and why field sports evolve.[7–9]

Virtually all sports evolve across time because of changes to rules and game tactics, increases in professionalism, use of new technologies, global exposure, and transformations in training and selection pressures affecting player physiology, morphology and motor skills.[10] Understanding these evolutionary patterns has, in other sports, been used for a range of applications. These include estimating future game and training demands,[11] assisting in player selection and talent identification,[7] understanding injury aetiology,[9] and predicting the impact of rule changes and general drivers of change on the transition of field sports into the future.[8,10,12]

The aim of this study was to quantify elements of game structure and speed, including play and stop periods, ball speed, player density and passing rates in elite-level soccer played in World Cup finals over the period 1966–2010. These patterns of change are used to build a framework of potential drivers of evolutionary pressures operating in soccer over the longer term.

2. Methods

The study was a retrospective correlational design to quantify longitudinal changes in the final game of each of the 12 World Cup soccer tournaments between 1966 and 2010. Commercially available broadcast quality video footage of World Cup finals between 1966 and 2010 was used. Each game was assessed for quantifiable variables of game structure and play patterns, with the same observer measuring all games to ensure consistency of measurement skill and interpretation of variables recorded. Games last for approximately 90 min, made up of two 45 min halves and additional injury time at the end of each half. Extra time is played in a World Cup final if the scores are tied. Extra time (if applicable) was not included in this analysis.

Play and stop period durations were timed using TrakPerformance software (SportsTec Australia; http://www.sportstec.com). A play period began at the start of each half and continued until a stop event occurred such as a free kick or the ball exited the playing field. Play periods re-started when the ball returned to the field via a kick or throw. The frequency and duration of play and stop periods were recorded for each game. The totals were also used to assess the time the ball spent in and out of play, as well as a percentage of play time in the final game time.

Stop periods were further categorised to provide the duration and frequency of different match events. The stop events or 'stoppages' were timed manually on a separate occasion using a stopwatch to the nearest 0.1 s and were coded as throw-ins, corner kicks, goal kicks, injuries, substitutions, goals and free kicks. Free kicks were separated into two groups: a direct shot at goal where there was no pass to a teammate, although a touch to set the ball rolling for a team mate was acceptable as part of this definition, and all other free kicks. An event was recorded as an injury only if a medical officer or trainer was required, or if the ball was deliberately put out of play with the sole intention of tending to a player. Play and stop period intra-tester reliability was assessed using repeat measures of two games. Inter-tester reliability was calculated by comparing the averages of the repeat measures to the averages of duplicate games of a second tracker.

TrakPerformance software was used to measure the speed of the ball, which is our measure of game speed. The method involved a computer-based tracking system where the tracker visually and mechanically tracked the movement of the ball using a scaled, miniaturised playing field and tracking pen. As the ball moved around the field the tracker mirrored this movement across a tracking tablet or computer screen. The movement was calibrated to represent the true displacement of the ball over the field and was used to calculate ball speed (m/s). Mean ball speed was calculated using the speed of all the individual play periods within a half or entire game.

Previous studies have shown the reliability of the tracking system to be within 5–7% of the true distances, and not different from GPS measures.[22] However, it is also known that experience in tracking plays an important role in the accuracy of the measures.[12,13] Therefore, prior to collecting data for the study, duplicate measures of two games were completed (JW) to assess intra-tester reliability. The ball speed values were also compared to duplicate measures of another tracker (KN) to quantify inter-tester error.

Player density is defined as the congestion of players around the ball. Creating high density is often a strategy used to place additional defensive pressure on the ball-carrier while low density is preferable when attacking to allow space and time for decision making and ball possession, and when shooting for goal. Player density is operationalised as a measure of the number of players within an estimated 5 m of the ball. Player density is a fluid and constantly changing variable within a game that is difficult to measure continuously with present technologies. Therefore, a count of the number of players within a 5 m radius of the ball was made at each 15 s increment across the game. If the ball was out of the playing field, was not 'in play', or if there were no players within 5 m of the ball nothing was recorded for that interval.

The 5 m radius required a level of subjectivity and estimation. To assist, several techniques were used to increase the accuracy of this judgement. Player heights are known to average approximately 1.8 m so players within the vicinity of the ball could be used as a guide to distance. Also, known distances on the field, such as the central circle or boxes at each end, were also used as these have specified dimensions. The consistent patterns of the grass preparation were another method used to judge the 5 m radius. Measures of intra-tester reliability were made that involved taking five repeat measures of one half, with at least one day between trials.

Passing rate is an indicator of game style and skill demands. A pass was defined as the deliberate act of striking the ball to maintain team possession, even without a defined target. This included attempted passes that were blocked or intercepted. Strikes that were intended to clear the ball out of play and shots at goal were not included. Kicks from set pieces such as corners and free kicks were also not included. Passes were counted manually for each half and the total was divided by the total play time measured by TrakPerformance to give a rate of passes per minute of play time. Passing rate error assessment involved duplicate measures across a game. The mean percent difference between the two samples was calculated.

The commercial broadcast footage uses replays of specific aspects of the game to enhance viewing experience. The replays occasionally prevented precise measurement so an exclusion criteria was used: ball speed and play duration were recorded from the position of the ball when normal viewing returned; player density intervals were recorded as missing for this interval in line with when the ball was out of play; stop period event times were recorded as missing if either the start or stop times were immeasurable.

The study is based on only 12 games over a 44-year period and the World Cup finals may not be representative of soccer in

Table 1
Frequency of stop events in each World Cup final game (1966–2010). Parentheses indicate the number of events that could not be timed accurately due to technical (video) limitations. The total column includes the number of timed and untimed events.

Year	Corners	Free kicks	Free kick at goal	Goal kick	Throw in	Goal	Substitution	Injury	Total
1966	13	35 (1)	2	30	44 (1)	4	0	0	130
1970	8	28 (1)	10	29	27	4 (1)	2	2	112
1974	19	46	4	16 (1)	26	3	1	1	117
1978	9	56	6	9 (1)	32 (1)	2	4	2	122
1982	7	40 (3)	3	26 (1)	40	0 (4)	4	1	129
1986	13	59	5	12 (2)	36	5	2	1	135
1990	4	40 (3)	4	15	27 (1)	1	1	6	102
1994	5	30 (1)	3	15 (1)	32 (2)	0	2	1	92
1998	12	29 (1)	3	12 (4)	40 (1)	2 (1)	4	7	116
2002	16	27 (8)	3	17 (1)	39 (2)	1 (1)	5	4	124
2006	8	30 (6)	3	16 (5)	37 (6)	0 (2)	3	5	121
2010	10	32 (6)	4	13 (4)	48 (2)	0	3	5	127

general. It is also clear that games can vary widely depending on environmental conditions, team strategies, refereeing style and score-line.[14,15] Even within games variables such as game speed and player density can differ considerably.

Games were analysed as halves and whole games to determine trends within games and across time. The level of significance was set at $p < 0.05$ unless otherwise stated. Variables were analysed with paired and independent *t*-tests, non-parametric tests for the skewed player density data and linear regression analysis to assess changes across time.

3. Results

Intra-tester reliability trials showed no significant difference between total play time (mean error = 1.8%; $p = 0.647$) or total stop time (0.5%; $p = 0.981$). There was a 2.9% difference between the number of recorded play periods in the repeat trials. The second tracker recorded intra-tester reliability of 1.8% for total play time ($p = 0.650$) and 2.2% for total stop time ($p = 0.355$) across repeat measures. Inter-tester comparisons showed there were no significant differences between the two trackers for play time (3.2%; $p = 0.638$) or stop time (6.6%; $p = 0.591$).

The total number of game events between duplicate measures showed no difference (0%), while the summation of stop time of the game events showed an average difference of 6.4%. There were no significant differences in times recorded for throw-ins (mean difference = 0.1%; $p = 0.877$), corner kicks (1.0%; $p = 0.927$), goal kicks (0.4%, $p = 0.950$), or free kicks (0.2%; $p = 0.957$) across the duplicate measures.

The percentage of game time where the ball was in play averaged 5.1% less in the second half compared to the first half (mean = 61.4% v 56.3%; $t = 3.08$; $p = 0.011$). This was due to both a decrease in play time in the second half (mean = 1653 s v 1522 s; $t = 2.81$; $p = 0.071$), and a similar increase in stop time (1040 s v 1192 s; $t = 1.16$; $p = 0.009$). Regression analysis showed total play time remained relatively constant ($r = 0.306$; $p = 0.145$), while total stop time increased ($r = 0.502$; $p = 0.012$) over the period 1966-2010. These changes resulted in a decreased percentage of play time from 70.1% in the earliest game to 51.8% in the most recent World Cup (predicted average of 64.2% down to 53.6%; Fig. 1).

Regression analysis of all play periods ($n = 1635$) across the period 1966 and 2010 showed a decrease in the average play duration equal to about 4 s from 29 to 25 s ($y = 206.5 - 0.09 \times x$; $p = 0.037$). Analysis of all stoppages ($n = 1670$) showed an increase in the average stop period duration by about 7 s to around 17 s in the most recent game ($y = -287.8 + 0.154 \times x$; $p < 0.0001$).

Table 1 shows the type and frequency of specific stop events. The number of stops per game averaged 119 ± 12 between 1966 and 2010 and did not change over time ($p = 0.8071$). There were no changes in the number of specific stop events across time except for an increase in the number of injury stoppages ($y = -228.2 + 0.11626 \times x$; $r = 0.71$; $p = 0.009$).

Across the period 1966 to 2010 there were significant increases in the average time taken for throw-ins (approximately 8–12 s; $y = -149.15 + 0.080 \times x$; $r = 0.21$; $p = 0.0001$), corner kicks (19–26 s; $y = -293.52 + 0.159 \times x$; $r = 0.29$; $p = 0.0012$), and goal kicks (16–24 s; $y = -353.45 + 0.187 \times x$; $r = 0.35$; $p = 0.0001$). Regression analyses showed there were no changes in the average time taken to make substitutions (mean time 46 s; $p = 0.663$) or for injury stoppages (75 s; $p = 0.520$).

Fig. 2 illustrates a significant increase in the time taken for free kicks from an average of approximately 13 s in 1966 to 20 s in 2010. It also shows that free kicks for goal increased over time from an average of about 38 s in 1966 to 63 s in 2010. This positive relationship was unchanged when penalties ($n = 5$) were excluded ($p = 0.0043$).

Intra-tester reliability showed no significant difference in tracking distance (mean difference 2.6%; $p = 0.636$) or total play time (1.8%; $p = 0.647$). There was no difference in the individual play period speed (3.4%; $p = 0.744$). Intra-tester reliability of tracking distance and play time between trackers showed no differences (3.8%; $p = 0.754$ and 1.8%; $p = 0.650$, respectively). There was no difference in individual play period speed (8.7%; $p = 0.240$).

The inter-tester reliability showed no differences for tracking distance (3.2%; $p = 0.638$), total play time (0.4%; $p = 0.326$) and individual play period speeds (4.1%; $p = 0.161$). The difference in mean speed averaged 6.3%. The results both within and across testers showed acceptable reliability using the computer-based tracking technology and are in line with previous findings.[13]

Fig. 1 illustrates game speed increased significantly across the study period. The regression line shows game speed increased from an average of approximately 8.0 m/s to 9.2 m/s, a 15% elevation across the period 1966–2010. Paired *t*-tests showed no significant difference between halves for average game speed ($t = 0.88$, $p = 0.398$).

There were no significant differences in player density measures across the repeat reliability trials ($p = 0.7128$). Player density measures are markedly skewed. Spearman's rank correlation analysis of all player density data points within each game ($n = 2184$) over time showed an increasing trend ($p < 0.0001$).

Reliability using repeated measures showed an error of 3.0% difference in the number of passes recorded across the game measured. In the World Cup finals analysis there was a significant increase in passing rate from 1966 to 2010. The regression line shows an increase from about 11.3 to 15.3 passes/min playing time shown in Fig. 1.

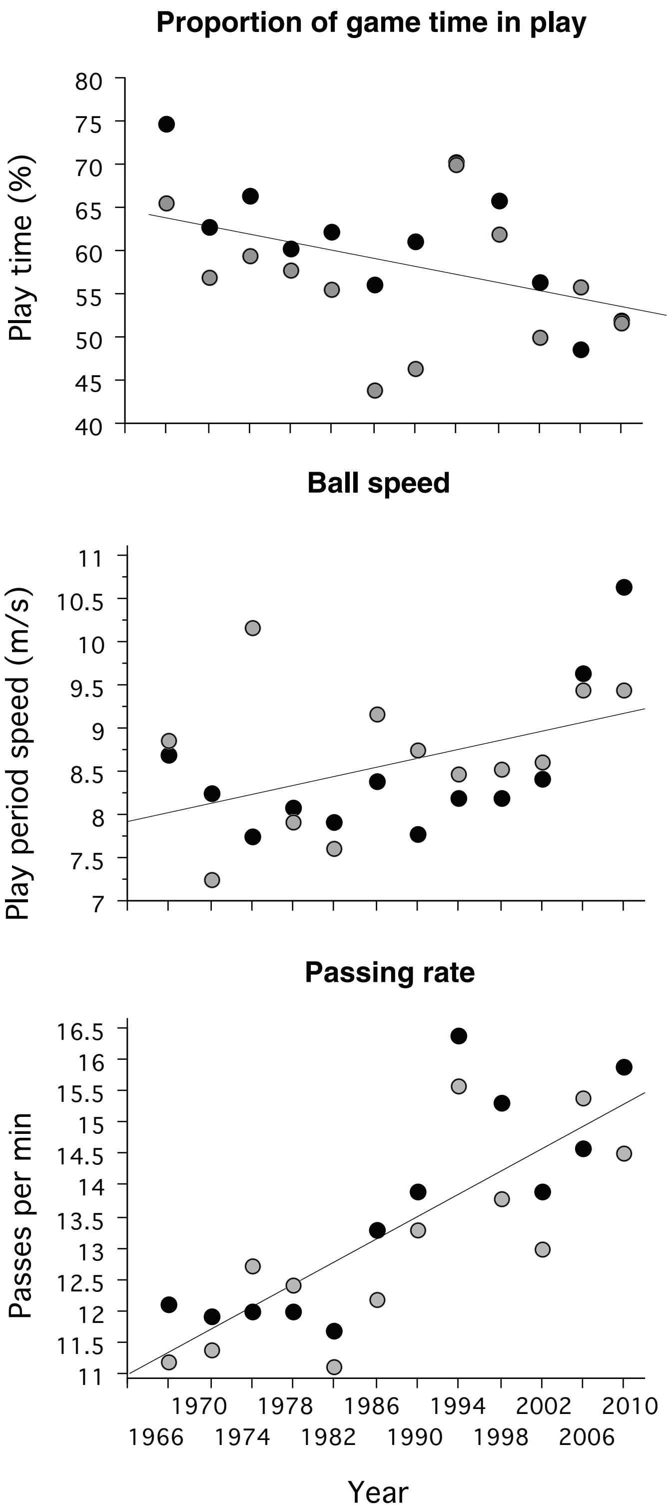

Fig. 1. Play structure patterns in World Cup finals from 1966 to 2010. Top panel shows regression of play time as a percentage of overall game time ($y = 539.8 - 0.2419 \times x$; $r = 0.44$; $p = 0.032$). Centre panel is game speed using ball tracking ($y = -42.958 + 0.026 \times x$; $r = 0.446$; $p = 0.029$) and bottom panel shows passing rate per minute ($y = -166.194 + 0.090 \times x$; $r = 0.796$; $p < 0.0001$). Darker circles are first half measures.

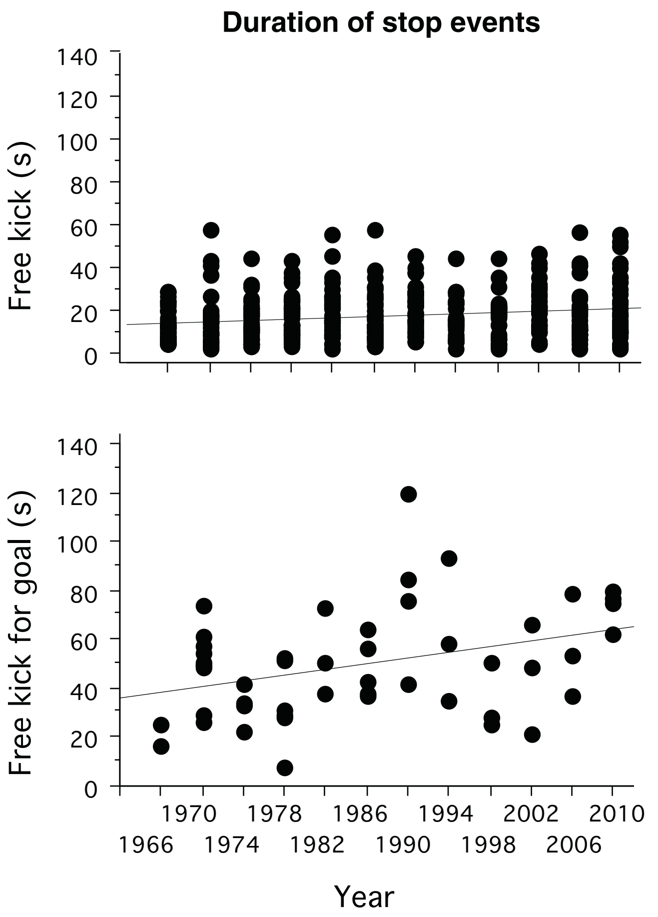

Fig. 2. Duration of free kick stop events in World Cup finals from 1966 to 2010. Top panel shows free kicks not for goal ($y = -277.50 + 0.148 \times x$; $r = 0.18$; $p = 0.0001$); bottom panel shows free kicks for goal ($y = -1088.4 + 0.573 \times x$; $r = 0.36$; $p = 0.0104$).

4. Discussion

Ball tracking and notational analysis were used to assess the evolution of World Cup soccer finals played in the period 1966–2010. Specifically, the study quantified ball speed, the duration and frequency of play and stop periods, player density and passing rates. The study has demonstrated elite level soccer has undergone substantial changes in game speed, structure and play patterns. These changes are not random but rather illustrate models of game speed and patterns that are likely to confer an advantage in terms of success at the highest level.

Field sports have game structures involving patterns of attacking and defending play periods interspersed with stoppages. The results show the total number of stoppages was unchanged over time but there were consistent increases in the average duration of almost all stop events. Therefore, the increase in total stop time found was due to increased duration of stop events rather than frequency of stoppages. The way in which these play and stop periods 'unfold' during games and interact is important for a number of reasons. They directly impact potential work-to-recovery ratios, influence opportunities to rest, and determine the intensity with which players can compete during subsequent play periods.[16] These fatigue-related interactions have changed over the 44-year period such that an average work: recovery ratio (play period duration:stop period duration) has decreased from around 4:1 in 1966 to 1.5:1 in 2010 and is also reflected in the lower play time relative to the total game time (Fig. 1). Game structure impacts physical demands on the players, for example, the trend towards shorter, higher intensity play periods. The current pattern of shorter play periods with longer recovery periods facilitates higher game intensity when play resumes.[17] As a consequence, players impact game structure through their control over stop duration where they will often extend this time to aid in recovery and set up structures. As a spectacle this is often exciting and adds to the drama but there are obvious drawbacks. These include an increased probability of injuries through high-speed collisions involving greater kinetic energy[9] and when moving at sprint speeds more frequently.[18] Interestingly the only game stoppage event to increase in frequency over time was for injuries although these stop events can also be used strategically.

Stoppages have become critical elements of soccer games where set plays and tactics enhance goals scoring opportunities.[19] This is reflected by 'set piece specialists', or players who have skills and abilities in particular events such as kicking with a significant curve or taking long throw-ins. Fig. 2 shows the trends in stop duration for direct and indirect free kicks. While they are both increasing over time, the rate of change as indicated by the slopes of the regression lines, is almost 4-fold higher for the set shots, reinforcing the importance of these relatively rare game events in goal-scoring.[19]

Using the ball speed in a field sport such as soccer to quantify game speed has only rarely been reported.[10,12,20] This is despite the fact ball speed has a fundamental bearing on the speed of player movement and decision-making, for example to intercept or reach a pass, determines a skill set that the game demands, and is routinely measured and reported in many other sports such as racquet (tennis and badminton), and throwing sports (cricket, softball and baseball). This may be because there is no general consensus of what game speed is, how it should be measured, and until recently, technical difficulties in measuring it.[2] Notwithstanding, in this study the game speed increased by 15% across the period reviewed. In a similar way, Australian football (AF) has also had increases in game speed, doubling over a 50 yr period to the late 1990s.[12]

The question becomes what drives this evolutionary pattern? That is, what is the advantage of playing faster that might lead to this change over time? There is evidence to suggest a performance advantage in playing with speed in invasion-style field sports, particularly at times when moving closer to goal and during phases of transition from defending to attacking.[3] Using a metric called a centroid, or vector-averaged position of players within a team, the attacking teams were at an advantage and more likely to score when their centroid moved faster in a transition period relative to the defender's centroid. Vilar et al.[4] used an ecological dynamics model to help explain playing patterns and interactions among soccer players. They found attackers were constantly attempting to break symmetry with their nearest opponent while defenders tried to maintain symmetry by staying between the attacker and the goal. In situations where goals were scored an advantage was achieved when attackers moved faster, both before and after receiving the ball, than their immediate defender. Successful defenders also achieved higher velocities relative to the attackers to intercept the ball trajectory.[13] Others have found the amount of high speed running intensity activity is related to the overall success of the team.[21,22] This is consistent with reports showing the need for high intensity running and repeat sprint ability in the modern game and how these have increased compared to games in previous decades and as the level of competition increases.[17,23] Finally, ball speed in AF was shown to be positively correlated with playing level, larger grounds and dry conditions.[9]

Together, these results reinforce the advantage in faster game speed. The high-intensity movements impact the game demands and speed attributes of elite players and create a relentless search for faster players and playing styles, and concomitant skills required for these demands.

The results showed player density has increased over time. Player density is an indicator of congestion and this plays an important part in successful and unsuccessful patterns of team play. For example, the distance between attackers and defenders is a critical feature of goal success where attacking players try to open space or create space between them and defenders while at the same time successful defenders try to close space to constrain scoring angles and force rushed skill execution.[4] Creating space requires speed, early movement and anticipatory skill, and it also involves decreasing player density when in possession of the ball. Decreased player density allows players more time and space and the probability of scoring in soccer doubles if there is more than one metre of free space around the kicker when shooting for goal.[24] Defenders, on the other hand, try to increase player density around the attacker and this involves matching attackers for speed and early anticipatory movements,[4] so it is not surprising that attackers and defenders show the highest levels of sprinting in games.[17]

Raising player density leads to elevated levels of skill, speed and precision required to move through the player traffic, increases the number of variables included in decision-making, while at the same time forces players to hurry selections.[24] Greater congestion obliges players to accelerate, decelerate and change direction more often to avoid other players, and to find space and break away from contests. Not only is this physically demanding but may lead to more contests and associated collisions,[14,15] and may be a factor behind increased injury rates in soccer.[25–27] Higher player density and associated man-to-man marking induces higher blood lactate levels and leads to greater fatigue compared to a zoning defensive strategy.[28]

Player density, therefore, is a balance between attacking forces to create space and defensive actions to close space, adjusted to levels of fitness and fatigue within the game. The long-term trend showing increasing player density at the highest level suggests an evolution towards greater defensive strategies matched with superior skill and fitness. This is supported more broadly, although anecdotally, whereby contemporary play styles promote 'compactness' where players are concentrated in a relatively narrow band in the central regions of the field, particularly when defending, compared to games of yesteryear. Both elite-level AF and World Cup Rugby Union have also demonstrated increases in player density in recent decades suggesting the success of these common defensive threads among field sports.[29]

Passing rate increased linearly by around 35% across the time period studied. This measure illustrates the increased intent or need to move the ball more often, rather than holding the ball up or playing long passes, a style more characteristic of the earlier World Cup games. Fast ball movement or game speed is generated through a combination of high passing rates and high ball speed (in addition to faster player movement when in possession of the ball), and has been shown to be critical for success,[3] and to differentiate elite from non-elite players in tests of soccer skill.[30] Successful teams at the World Cup level have also been found to have significantly greater passes per game than less successful teams. Moreover, since previous work suggests player proximity is a key factor in skill execution,[24] the higher passing rate and player congestion in modern games, mean today's elite players require faster decision-making, and skill. This is undoubtedly selected for through the developmental years and then rehearsed as full-time athletes. These attributes will be even more critical in the future if game speed and passing rates continue along the evolutionary trajectories found.

Comparing distances covered across soccer studies shows it has become more physically demanding over time,[2] although it has been difficult to quantify this in consistent and comparable ways. The changes in World Cup soccer finals shown in the current study all indicate the physical demands are increasing. Defensive actions in a dense player environment where the emphasis is placed on number superiority, the need for speed in the transitions, the advantage of rapid attacker 'spread' when there is a defensive-to-offensive turnover, all demand superior fitness. In response, and in line with the human power curve, players will extend recovery periods when they can to help mitigate fatigue. Although speculative, if left unchecked the game will likely become even more intense characterised by shorter, intense play periods. In turn, this game style will suit bigger, more powerful athletes who will have time to recover in the longer stoppages.

5. Conclusions

This study on performance analysis has described emergent team and game structure patterns over the longer term. Soccer at the highest level has evolved significantly and will likely continue to change. While the causative factors are not known, the functional interaction of players and environments form predictable and successful patterns. The persistent trend towards these stable blueprints, such as increasing player density, game speed and passing rates, within a sport having very few rule changes and with parallels in other field sports, suggest common evolutionary pressures are operating. To increase the probability of game success within a complex team sport requires rapid self-organisation in a dynamical system, underpinned by prediction speed and accuracy, skill and fitness. The trends found over the longer term suggests professionals are getting better at these through the processes of self-selection, conditioning, and positive feedback of successful strategies.

Practical implications

- Selection needs to prioritise speed as a critical element in elite-level soccer.
- Future game demands are likely to require faster decision-making athletes.
- Current trends suggest larger, powerful athletes will be tolerated by the sport because of the longer stoppage breaks facilitating more complete recovery.

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