Match-to-Match Variability of High-Speed Activities in Premier League Soccer

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Key words
- between-match variation
- physical performance
- position

Abstract

The aim of the present investigation was to determine the between-match variability of high-speed running activities completed by a large sample of elite players over an extended period of time. A further aim of the study was to determine the influence of playing position on the magnitude of this variability. Observations on individual match performance measures were undertaken on 485 outfield players (median of 10 games per player; range = 2–57) competing in the English Premier League from 2003/2004 to 2005/2006 using a computerised tracking system (Prozone®, Leeds, England). High-speed activities selected for analysis included total high-speed running distance (THSR), high-speed running (HSR), total sprint distance (TSD) and the total number of sprints undertaken. Total high-speed running distance in possession and without possession of the ball was also analysed. Match-to-match variability was generally high across all variables with a mean CV of 16.2 ± 6.4% (95% CI = 15.6–16.7%) and 30.8 ± 11.2% (95% CI = 29.9–31.7%) reported for HSR and TSD covered during a game. This variability was generally higher for central players (midfielders and defenders) and lower for wide midfielders and attackers. Greater variability was also noted when the team were in possession of the ball (~30%) than when they did not have possession (~23%). The findings of the present study indicate that match-to-match variability in performance characteristics of elite soccer players is high. This inherent variability means that research requires large sample sizes in order to detect real systematic changes in performance characteristics.

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Introduction

High-speed activity accounts for approximately 8% of the total distance covered during match-play [27]. The amount of high-speed exercise may, however, serve as a valid measure of physical performance during soccer match-play since it differentiates between different standards of play [23,24], the tactical role of players [12,13,21], is sensitive to the effects of training [19] and is related to the overall success of the team [13,27].

Like all measures of sporting performance, high-speed efforts in soccer match-play are not stable properties but are subject to variation between successive matches. Changes in the physical condition of the player [21,24] and environmental conditions [16] will lead to within-subject (player) or between-match variation in high-speed activity across the competitive season. Superimposed upon these factors is variability that also exists when match-to-match observations are completed in short time spans (e.g. game to game) where factors such as fitness are unlikely to change. Under such conditions, changes in the tactical role of players [12,13,27] and the self-imposition of physiological stress by the players themselves [14] are likely to lead to marked variability. As a consequence of the variation that is likely to be mediated through both the inherent demands of the game and the individual's ability to regulate their own activity, the variability in high-speed activity in soccer is likely to be relatively large.

Variability in key performance measures has previously been quantified in sports such as athletics and cycling [10] where athletes are frequently required to perform relatively simple timed bouts of maximal exercise. In contrast to these sports, soccer performance is a construct where a multitude of different performance components or indicators interact together at both the level of the player and team [2]. The determination of between-match variability for specific compo-

nents of match performance is important since such components are typically simulated in laboratory [15] and field tests [25]. The description of performance variability can also be important for predicting statistical power in research as well as how worthwhile a certain intervention is for performance [3].

Limited data are currently available with respect to the inherent variation in match performance profiles of players. Observations on elite players have reported between-match variation in the region of 3–15% of the distance covered for a number of activity classifications [6,24,27] with similar data reported for match officials [21]. Whilst these data provide useful insights into match performance variability, such values are unlikely to represent the true match-to-match variation for high-speed activities since estimates are based upon the variability between two successive matches for a limited number of performance indices. Variability between matches is likely to be influenced by a myriad of factors, consequently multiple longitudinal observations over an extended period of time are required to provide a more comprehensive estimation of the between-match variability in match performance indices.

The use of semi-automatic computerised tracking systems [13,27] now means that more detailed analytical evaluations of the specific elements of an individual player's match performance can be generated for a large sample of players over an extended period of time. These data sets therefore provide a unique opportunity to evaluate the between-match variability in high-speed activities in elite soccer players. Therefore, the aims of the current investigation were to: (1) determine the between-match variability of high-speed running activities completed by a large sample of elite players over an extended period of time and (2) to determine the influence of playing position on the magnitude of this variability. This investigation also attempted to evaluate (3) if there are any changes in the amount of variability in high-speed running completed by players across a number of competitive seasons and (4) to determine the magnitude of the variability between matches played within a short time frame.

Methods

Players and match data

Match physical performance data were collected from 485 soccer players competing in the English Premier League during the 2003–2004 (S1), 2004–2005 (S2) and 2005–2006 (S3) domestic seasons. A total of 7281 individual match observations were undertaken on outfield players (goalkeepers were excluded) with a median of 10 games per player (range = 2–57). Only data for those players completing entire matches (i.e. 90 min) were included for analysis.

The study conformed to the ethical standards of the International Journal of Sports Medicine (17).

Data collection and analysis

Match performance data were produced using a computerized, semi-automated multi-camera image recognition system (Prozone®, Leeds, England) as described by Di Salvo and colleagues [11]. This system has previously been shown to be a valid and reliable system for measuring match activity in soccer [11,13]. Players were assigned to one of five outfield positions: Central defender (match observations = 1828); wide defender (match observations = 1638); central midfield (match observations = 1711); wide midfield (match observations = 987) and attacker (match observations = 1117) to determine the influence of playing position on between-match variation in high-speed activities. A further analysis was also undertaken to determine whether any seasonal variation existed in between-match variability by examining data separately over S1 (match observations = 2266), S2 (match observations = 3656) and S3 (match observations = 1433).

The following high-speed activities were used: 1. Total high-speed running (THSR) distance (average running speed > 19.8 km/h over a 0.5 s time interval) 2. High-speed running (HSR) distance (average running speed from 19.8 km/h to 25.2 km/h over a 0.5 s time interval) and 3. Total sprint distance (TSD) (average running speed > 25.2 km/h over a 0.5 s time interval). Total high-speed running was also expressed as both total HSR distance completed with the respective players team in possession (HSRP) and without (HSRWP) possession of the ball. This distinction was made in an attempt to determine if the observed variation in high-speed activity was influenced by the tactical considerations associated with offensive and defensive actions. Further analysis of sprint activity (> 25.2 km/h) included the total number of sprints completed. The term "high-speed" was used to describe the intense activity classifications in the present investigation. Previous research in the area has chosen to classify such movements as "high-intensity" activities (13, 30). This change in terminology was a consequence of a failure to individualise the classification of intense actions to each players specific movement speeds. The inability to determine this relationship makes it difficult to relate any speed of movement to the specific range of intensities that can be completed by the player. The use of the term "high-speed" therefore prevents inappropriate assumptions regarding the relative intensity of running for each player (1). This change in definition does not, however, preclude the potential discrepancies in this type of data that will occur as a consequence of a wide variety of different threshold speeds been used within the available literature.

Evaluation of short-term between-match variability

To determine the magnitude of the variability in high-speed running activities between matches played within a short time frame, match physical performance data from 37 players were analysed across an 8-week period (September-November) during S3. Only those players completing a minimum of 4 games across the time period were included for analysis (range = 4–5).

Statistical analysis

Data were explored for parity with a normally distributed population using histograms. All data, including the large data-set for number of sprints in a match, were found to be reasonably normal in distribution. Therefore, data are presented as the mean ± SD. Between-match coefficients of variation (CV) and associated 95% confidence intervals (CI) were calculated for each variable and compared between different player positions using a one-factor (between subjects) general linear model. The residuals from this statistical model were found to be reasonably normal in distribution. Specific significant differences in estimated marginal means between playing positions were explored using independent *t*-tests incorporating the Bonferroni correction for control of type I error rate. Coefficients of variation were calculated by dividing the standard deviation of repeated performance data by the corresponding mean value for each player. These coefficients of variation were found to follow an approximate normal distribution.

Table 1 Influence of Playing Position on High-Speed Activity Profile.

High-Speed Activity	Central Defender (n = 1828)	Wide Defender (n = 1638)	Central Midfielder (n = 1711)	Wide Midfielder (n = 987)	Attacker (n = 1117)
THSR (m)	604 ± 164	951 ± 231	916 ± 253	1162 ± 247	941 ± 250
HSR (m)	459 ± 115	698 ± 155	718 ± 181	856 ± 172	670 ± 161
TSD (m)	145 ± 65	253 ± 96	198 ± 90	307 ± 109	272 ± 117
HSRP (m)	103 ± 66	368 ± 155	375 ± 191	616 ± 184	608 ± 177
HSRWP (m)	452 ± 121	528 ± 135	498 ± 163	490 ± 161	281 ± 127
total sprint number	20 ± 9	34 ± 12	30 ± 13	41 ± 13	34 ± 13

THSR = Total high-speed running distance; HSR = High-speed running distance; TSD = Total sprint distance; HSRP = Total high-speed running with team in possession of the ball; HSRWP = Total high-speed running without team in possession of the ball (mean ± SD)

Table 2 Overall and Short-Term Between-Match Variation for High-Speed Activities.

High-Speed Activity	Overall Coefficient of Variation (%)	Overall 95% Confidence Intervals	Short-Term (n = 37) Coefficient of Variation (%)	Short-Term 95% Confidence Intervals
THSR	17.7 ± 6.8	17.1–18.3	23.5 ± 21.8	16.2–30.7
HSR	16.2 ± 6.4	15.6–16.7	22.0 ± 22.1	14.7–29.4
TSD	30.8 ± 11.2	29.9–31.7	38.9 ± 29.9	29.0–48.9
HSRP	30.6 ± 13.3	29.5–31.7	38.7 ± 26.8	29.7–47.6
HSRWP	23.5 ± 8.7	22.8–24.2	27.9 ± 22.1	20.5–35.3
total sprint number	30.0 ± 11.3	29.0–30.9	34.4 ± 27.4	25.2–43.5

THSR = Total high-speed running distance; HSR = High-speed running distance; TSD = Total sprint distance; HSRP = Total high-speed running with team in possession of the ball; HSRWP = Total high-speed running without possession of the ball (mean ± SD)

Table 3 Influence of Playing Position on Between-Match Variation for High-Speed Activities (% CV and 95% CI).

High Intensity Activity	Central Defender	Wide Defender	Central Midfielder	Wide Midfielder	Attacker	Follow-up Tests (Bonferroni)
THSR	20.8 ± 6.4 (19.6–22.0)	17.9 ± 6.6 (16.7–19.1)	18.8 ± 6.8 (17.6–19.9)	14.7 ± 6.4 (13.4–16.1)	16.3 ± 7.6 (14.8–17.7)	CM = CD > WD > WM = A*
HSR	18.8 ± 5.9 (17.7–19.9)	16.9 ± 6.2 (15.8–18.0)	16.8 ± 6.3 (15.8–17.9)	13.1 ± 6.0 (11.8–14.3)	15.2 ± 7.1 (13.8–16.5)	CM = WD = CD > WM = A*
TSD	36.4 ± 10.4 (34.5–38.4)	29.4 ± 10.9 (27.4–31.3)	33.6 ± 11.1 (31.7–35.5)	26.9 ± 10.2 (24.7–29.1)	26.8 ± 12.6 (24.4–29.1)	CM = CD > (WD = WM = A)*
HSRP	44.5 ± 12.7 (42.1–46.8)	33.4 ± 13.2 (31.0–35.8)	33.0 ± 13.8 (30.7–35.3)	22.0 ± 13.0 (19.2–24.6)	20.0 ± 14.7 (17.2–22.9)	CD > (WD = CM > WM = A)*
HSRWP	21.5 ± 8.1 (20.0–23.0)	20.6 ± 8.5 (19.1–22.1)	22.9 ± 8.2 (21.4–24.4)	23.4 ± 8.1 (21.7–25.2)	29.2 ± 9.7 (27.4–31.0)	A > (CD = WD = CM = WM)*
total sprint number	34.6 ± 10.6 (32.6–36.5)	29.5 ± 11.0 (27.5–31.4)	33.1 ± 11.2 (31.2–35.0)	24.9 ± 10.2 (22.7–27.2)	26.5 ± 12.6 (24.1–28.9)	CM = CD > WD > WM = A*

THSR = Total high-speed running distance; HSR = High-speed running distance; TSD = Total sprint distance; HSRP = Total high-speed running with team in possession of the ball; HSRWP = Total high-speed running without team in possession of the ball (mean ± SD). * Significant difference between playing positions ($p < 0.05$)

Results

Overall between-match variability in high-speed activity

Table 1 shows the high-speed activity profile (m) across the different playing positions. The overall variability (independent of playing position and seasonal variation) and associated 95% CI for each high-speed activity is displayed in **Table 2**. Match-to-match variability in performance characteristics was generally high across all variables.

Influence of playing position on between-match variability in high-speed activity

The between-match variability for all high-speed activities was influenced by playing position with central defenders and central midfielders generally displaying the greatest variability and wide midfielders and attackers the least ($p < 0.001$; **Table 3**). Variability in THSR and the total number of sprints in central defenders was similar to central midfielders but greater compared with wide defenders, wide midfielders and attackers ($p < 0.01$). The variability observed in central midfielders and wide defenders for both activities was also greater compared with wide midfielders ($p < 0.05$).

Central defenders and midfielders demonstrated a similar degree of variability in HSR and TSD but greater compared to wide midfielders ($p < 0.001$; **Table 3**). Greater variability in HSR was also observed in wide defenders relative to wide midfielders ($p < 0.001$). Lower variation was observed in attackers relative to central defenders for both HSR and TSD ($p < 0.001$). The variability in HSRP for central defenders was greater compared to all other positions ($p < 0.001$; **Table 3**). Wide defenders and central midfielders demonstrated a similar amount of variability in HSRP which was greater compared to wide midfielders and attackers ($p < 0.001$). Variability in HSRWP was greater in

Table 4 Influence of Seasonal Variation on Between-Match Variability in High-Speed Activity (% CV).

Season	THSR (% CV)	HSR (% CV)	TSD (% CV)	HSRP (% CV)	HSRWP (% CV)	Total Sprint Number (% CV)
2005–2006	17.0 ± 9.8	15.1 ± 9.1*	29.1 ± 16.1	28.3 ± 19.7 *	22.0 ± 12.5 *	28.6 ± 16.4
2004–2005	17.6 ± 5.6	16.3 ± 5.1	30.7 ± 9.1	30.8 ± 11.1	24.0 ± 7.1	29.8 ± 9.3
2003–2004	18.4 ± 4.7	17.1 ± 4.4	32.0 ± 7.7	32.6 ± 9.3	24.7 ± 5.9	30.8 ± 7.8

THSR = Total high-speed running distance; HSR = High-speed running distance; TSD = Total sprint distance; HIRP = Total high-speed running with team in possession of the ball; HSRWP = Total high-speed running without team in possession of the ball (mean ± SD). * Significant difference between 05/06 and 03/04 ($p < 0.05$)

attackers compared to all other positions ($p < 0.001$). No other differences were observed between the remaining positions (▶ **Table 3**).

Influence of seasonal variation on between-match variability in high-speed activity

The variability observed in HSR distance, HSRP and HSRWP declined from 2003–2004 to 2005–2006 ($p < 0.05$; ▶ **Table 4**).

Short-term between-match variability in high-speed activity

The variability (independent of playing position) and associated 95% CI in high-speed activities between matches played over an 8 week period during S3 is displayed in ▶ **Table 2**. Match-to-match variability reported for each activity was generally high and greater than the equivalent values reported across S1–S3.

Discussion

Limited data are available on the between match variability of high-speed activities in elite soccer players. This manuscript provides unique data for the literature as it not only includes a sample size that exceeds that of previous relevant investigations but also examines the variability in specific types of high-speed running. Our data also enables the variability in high-speed activity to be compared across three competitive seasons and in relation to playing position. From our analysis, it was clear that all high-speed activities demonstrated high CVs (~16–30%). This variability was to some extent influenced by the team having possession of the ball, playing position and the season in which the data were collected. Overall these data would suggest that players do not re-produce consistent high-speed activity profiles across games played over time. This finding has implications for both the interpretation of the high-speed activity completed by players during games and also its use as an indicator of performance in applied research studies.

The few researchers who have attempted to examine the between-match variation in an individual's work-rate have tended to use relatively small samples of players ($n < 20$) [6,24,27]. These issues have been somewhat addressed by the multi-camera semi-automated analysis systems used in recent investigations [13,27]. Bangsbo et al., [6] provided one of the first reports of the variation in the work-rate of soccer players between competitive matches. The variability they observed did not seem to be related to the amount of high-speed running that was performed suggesting that any inherent variation in the total distance covered was a consequence of differences in low-speed not high-speed activities. The high-speed running distance within a game was therefore suggested to be a relatively stable indicator of performance.

Our data would suggest that the between-match variation in the high-speed activity of players is substantial being greater than that observed previously [6,24] and confirming the variation previously seen using a similar methodological approach to the collection and classification of data [27]. We would suggest that the large sample size and longitudinal data collection methods used in the current investigation are able to provide the most precise estimates of the between match error in high-speed activity that are currently published. This relatively high precision of estimate of match-to-match variation is illustrated by the narrow confidence intervals we report for our CV data. It would therefore seem that the high-speed activity within a game does not provide an accurate indication of an individual's capacity to perform high-speed activity if it is based on a single observation. This would suggest that when using this method of analysis and the current classification system a number of repeat measurements need to be obtained if a true representation of a player's ability to complete high-speed efforts is required. This may significantly extend both the data collection and analysis periods needed for this type of research.

The data provided here are also, to our knowledge, the first in which the between-match variability of specific high-speed activities has been identified. Previous researchers [e.g. 9, 24, 27] reported the between-match variability for high-speed activity as a composite value of different types of activity (e.g. HSR and running) rather than a discrete CV for each specific type of activity. Identifying the variability associated with discrete components of high-speed activity (e.g. HSR, sprinting) would seem important as this information may not only provide a clearer indication of the specific fitness requirements of players within games but also enable researchers to identify which variables may most consistently reflect the intense efforts that are made within a game.

The lowest CVs were observed for THSR and the distance covered in HSR. The largest between-match variability was observed for sprinting. This would seem to indicate that players do not consistently produce their maximal efforts within games. Higher CVs (~30%) were also noted for the high-speed running completed when the team were in possession of the ball than when they did not have possession. Taken together, these data would seem to suggest that there are substantial differences in the variability of different indicators of high-speed activity. It would therefore seem pertinent in future studies to report the between-match variability in specific indicators of high-speed activity as opposed to those associated with variables that are based upon a composite of a number of activity classifications.

Another unique aspect of our investigation is the examination of the influence of seasonal variation on the between-match variability in high-speed activities. Data from three seasons between 2003 and 2006 illustrated significant reductions in the variability associated with HSR. These reductions seemed to occur irrespective of whether this activity took place with or without the ball. The overall variability in the total high-speed running distance was not, however, significantly reduced predominantly as a consequence of the high CVs maintained across all seasons for

the total sprint distance. The failure to find a consistent pattern in changes in indicators of high-speed activity between season 2003–2004 and 2005–2006 makes it very difficult to determine if the overall variability in high-speed work-rate has actually reduced in this time span. If such changes do exist they may be a function of developments in the high-speed work-rates completed within a game across this time-period [13].

A variety of factors may help to explain the large CVs for the between-match variability seen in our sample of players. It is clear that the playing style and tactical organisation of teams has the potential to influence the work-rate of players [28]. The influence of these factors on high-speed activity is, however, very difficult to analyse as the specific strategies of coaches for specific games is not widely reported. Previous investigations [13,27] have demonstrated that playing position can also affect the high-speed activity completed by players. As a consequence we focussed our initial analysis on the influence of this factor on the consistency of an individual's high-speed activity pattern in our sample. An analysis of the data in relation to playing position showed clear differences between defenders, midfielders and attacking players. As the players positioned in wide areas of the field that are frequently reported to display the most tactically flexible roles within the team [9], it was envisaged that these positions would demonstrate the largest CVs for intense activity. This was clearly not the case for our sample as the largest variation in high-speed activity tended to be observed in players who operated in central roles. This data may suggest that it is the match performance of the central positions that are most susceptible to differences in the overall intensity of the game and the tactics employed by the coach.

One other possible explanation for the between-match variability in the data presented is the time of the season at which the data was collected. Mohr et al. [24] observed a CV of around 24% in the distance covered in high-speed running in elite professional players across different stages of the season. This value is similar to the 10–20% change in high-speed activity observed by Rampinini et al., [27] for a sample of 16 players who were observed between 2 and 10 times between the first and last competitive games of the year. The large sample size of players included in this investigation necessitated the collection of data in a large number of games that took place across different stages of the season. This would clearly indicate that some of the between-match variability observed in our sample of players will be simply a consequence of the data being collected at different times of the season. The analysis of a sub-set of our data collected across a relatively short time period (8 weeks) provided a direct opportunity to identify the influence of time of the season on the between-match variability in high-speed activity (**Table 2**). The variability observed was not reduced when compared to the CVs of our larger sample indicating that the influence of the time of the season is relatively small compared to the other factors that may influence intense activity in games. This would seem to indicate that the factors that may be responsible for the inherent variation in the high-speed activities of players (e.g. changes in team formation, opposition, playing at home or away, outcome of the game, etc) are altered from game to game and not just across groups of games or phases of the season. This would seem to support our view that these parameters are not consistently produced by players across games. The data of Rampinini et al., [27] can also be used to support these ideas. They examined the within-subject error for 20 players playing against the same opposition within the same week. This approach enabled the researchers to reduce the number of factors (e.g. tactics) that may influence an individual's match activity as well as control those that may be important in determining the activity profile that may vary as a function of the stage of the competitive cycle (e.g. fitness). Under these circumstances the variability was reduced (CVs between 4.3 and 13.9%) though not removed. These observations, when taken together, would suggest that the stage of the season, though potentially an important confounding factor, does not explain the entire variability in the high-speed activity completed by players.

Bangsbo et al. [5] identified the difficulties in obtaining a precise assessment of the physical performance of competitors in a sport such as soccer. Obtaining a precise indicator of performance is important as without the selection of an appropriate dependent variable it is very difficult to formulate applied research studies to examine the impact of interventions that could potentially affect the success of an athlete or team [4]. Activity profiles of players are frequently used as sport-specific outcome variables in applied soccer-specific research studies. High-speed activity is especially important in this regard as a consequence of its perceived importance to match outcome [29]. The amount of high-speed running completed in games has therefore been used to illustrate the effectiveness of different training interventions [e.g. 18,20] and validate sport-specific fitness tests [e.g. 22,26]. Low between-match variability for high-speed activity would seem to be crucial to studies of this nature [18] as it will improve the precision of the estimation of the effect and will lead to a clear understanding of the effects of specific treatments or interventions [4].

The inherent variability observed in indicators of high-speed activity in the current investigation (especially in the 8 week sample) would cast some doubt on the appropriateness of high-speed activity as a stable enough indicator of performance [19]. This would especially be the case for investigations in which the research team have relied on a single estimate of high-speed activity pre and post intervention or for studies which have failed to quantify the between-match variability prior to their analysis of their intervention. These factors will lead to a reduction in the statistical power of the study and therefore a decreased sensitivity to detect changes in the dependent variables [14]. Batterham and Atkinson [7] provided a framework for evaluating the sample size required to detect the changes associated with interventions in sport-related research using a simple single-group design. Using their nomogram, and assuming that a meaningful difference for a given intervention could be in the region of 10% (this is probably a somewhat generous figure for sports-related research), we can predict the sample size that would be needed to accurately determine the "true" (i.e. statistically significant) impact of any intervention that utilises the activity profile within a game as an indicator of performance. Based on a CV of 20% (which is not the highest CV we observed), we would estimate that a sample size of at least 80 players would be required to make such meaningful inferences. This sample size would seem to be substantially greater than the majority that have been used in the literature and could therefore indicate that the majority of investigations in this area could be underpowered. The magnitude of the CVs we observed can also be discussed in relation to the appraisal of changes in performance outcomes in individual players [4]. For example, the CV of 23% for THSR means that only if an individual player improves this performance outcome by approximately 64% could one be

reasonably certain (95 % probability) that this is a 'real' change and not attributable to 'normal' between-match variation.

Conclusion

These data suggest that the high-speed activity completed by players during match-play is highly variable between matches. The observation that this variability is affected by factors such as playing position and having possession of the ball would seem to suggest that at least some of this variation is a consequence of changes in the tactical and technical requirements of the game. Other factors that may account for this variation could include the time of the competitive season at which observations are obtained, however, this effect seems relatively small. Recognising such variability would seem to be important for researchers in this area as it highlights that single observations cannot be used to accurately determine an individual's capacity to perform high-speed activity during a game. They would also seem relevant for the calculation of the sample size that may be required for the detection of meaningful differences in intervention studies. This type of data is also frequently used by practitioners within professional football to support strategies for training prescription and performance improvements. An awareness of the variability associated with this type of data may also help inform their judgements in the practical application of this information.

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