

## Research article

# A PILOT STUDY COMPARING TWO FIELD TESTS WITH THE TREADMILL RUN TEST IN SOCCER PLAYERS

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### ABSTRACT

This study compares the performances obtained during soccer-specific field tests of the 20 m multistage shuttle run test (MST) and the Yo-Yo intermittent endurance test (YIET), with the measured maximal oxygen uptake ( $VO_{2max}$ ) obtained in both field tests as well as that obtained in the traditional test of running to exhaustion on a treadmill (TRT), in young trained soccer players. Twenty-one National-level youth players performed, in random order, the MST and YIET to determine the relationship between the two field tests. From these, eight randomly chosen players performed their field tests as well as a TRT, equipped with an ambulatory gas exchange measurement device. Pearson correlation coefficient analysis showed that the players' performance (i.e. distance covered) in the MST and YIET was correlated ( $r = 0.65$ ,  $p < 0.01$ ). Players' performance in the YIET was not significantly correlated with the measured  $VO_{2max}$  obtained in the same YIET nor with the measured  $VO_{2max}$  obtained in the MST and in the TRT (all  $p > 0.05$ ). In contrast, significant correlations were observed between the players' performance in the MST with the measured  $VO_{2max}$  obtained in the same MST and in the YIET (both  $p < 0.05$ ); and attained almost statistical significance with the measured  $VO_{2max}$  in the TRT ( $p = 0.06$ ). The lack of association between distances covered in the YIET with all the measured  $VO_{2max}$  values suggest that measured  $VO_{2max}$  per se may not be suitable to characterize soccer players' intermittent endurance performance. In comparison with the MST, the YIET may be a more favourable field-based assessment of soccer player's endurance performance.

**KEY WORDS:** Yo-Yo test, beep test, maximal oxygen uptake, intermittent, continuous.

### INTRODUCTION

Aerobic endurance fitness is important for soccer players (Helgerud et al., 2001). The standard test for assessing aerobic endurance fitness is the direct measurement of the player's maximal oxygen uptake ( $VO_{2max}$ ) whilst running to exhaustion on a treadmill (TRT) in the laboratory environment. Although the value obtained is considered the 'gold standard' for the measurement of aerobic power (Costill, 1967; Saltin and Astrand, 1967), the procedure demands time, expensive equipment and trained personnel. Therefore, it may not be ideal for team sports like soccer where testing every player will take valuable

time away from training. For this reason, there is keen interest among coaches in predictive field-based tests that may serve as convenient surrogates to directly measured  $VO_{2max}$  when assessing aerobic endurance performance in soccer players. There are two such popular tests, the 20 m multistage shuttle run test (MST) and the Yo-Yo intermittent endurance test (YIET) (Aziz et al., 2004; Bangsbo, 1996; Castagna et al., 2003; Davis et al., 1992; Erith, 2004; Malina et al., 2004; Metaxas et al., 2005; Oliveira et al., 2001a; 2001b; Tumilty, 2000).

Both the YIET and MST involve running at variable speeds across a 20 m distance, interspersed with frequent dynamic twisting and changing of

direction that is deemed to be specific to soccer movements. However, the MST involves a more continuous-type running protocol while the YIET has a five second recovery period after each shuttle run of 40 m. It was perceived that the inclusion of this short active recovery interval in the YIET replicates more closely the typical high-intensity intermittent running interval that is inherent in soccer match-play (Bangsbo, 1996). Performance during both field tests has been validated against measured  $\text{VO}_{2\text{max}}$  obtained during treadmill running in soccer players (Dourado et al., 2001; Kiss et al., 2001; Metaxas et al., 2005). With the availability of the state-of-the-art ambulatory device for gas exchange measurements however, researchers have begun to explore the opportunities for assessing athletes' fitness in the field rather than in a laboratory setting. Therefore, the purpose of the present study was to compare the physiological responses and performance of soccer players obtained during the two field-based soccer-specific tests (i.e. between the MST and YIET), as well as with that of the TRT, using an ambulatory gas exchange device.

## METHODS

### *Subjects*

Twenty-one young soccer players participated in the study. The players' physical characteristics are (mean $\pm$ sd): age, 17.7  $\pm$  0.4 yr and height, 173.9  $\pm$  5.6 cm and body mass, 63.8  $\pm$  7.4 kg. Players were informed of the tests' protocols and procedures, but to ensure that players put equivalence of effort in all trials, the aim of the study was not disclosed. All players were from the National Under-18 squad and have been playing competitively for at least three years. At the time of the study, the team was in the midst of a league competition, and was training four times a week for ~90 min per session and had a match every weekend. All players were familiarized with the tests' protocols and had undergone the MST, YIET and TRT at least once prior to the study. Both the players and their parents provided written informed consent for the study, which was approved by the institutional ethics review committee.

### *Procedures*

The three test trials were conducted as separate sessions interspersed between 3-4 days for each player. The YIET and MST were conducted as randomized balance trials among the 21 players. The TRT was conducted only after each of the chosen eight players had completed their two field tests. All test trials for each player were completed within three weeks. All trial times for each player were standardized within 1 hr, conducted between 0830 to

1030 hrs. Both the YIET and MST trials were conducted at the same roof-covered outdoor location. The temperature and relative humidity at the test site were consistent throughout the study, ranging between 29.5-31.5 °C and 76.5-79.5% respectively. Players either ran alone or in small groups of not more than three athletes and were instructed to exert maximal effort and were verbally encouraged to run for as long as possible. Players wore the same running shoes/trainers for all their test trials. Standardized warm-up for the MST and YIET trials consisted of 3 min of running back and forth the 20 m distance at a set pace (i.e. 8.0 km·h<sup>-1</sup>) via "beep" sounds emitted from a compact disc player. This was followed by 5 min of self-stretching focusing on the lower limb muscles.

### *20-m multi-stage shuttle run test (MST)*

The MST was conducted as previously described (Davis et al., 1992). Briefly, players ran back and forth between two lines, spaced 20-m apart, in time with the "beep" sounds from a compact disc (20-m Shuttle Run test CD, Australian Sports Commission). Each successful run of the 20-m distance was a completion of a shuttle. The "beep" sounded at a progressively increasing pace with every minute of the test and correspondingly the player must increase his running speed accordingly. The player was warned if he did not reach the end line in time once. The test was terminated when he i) could not follow the set pace of the "beeps" for two successive shuttles, and/or ii) stopped voluntarily. Typically the scores in the MST are expressed as levels and shuttles, but these values are discontinuous and cannot be used in statistical analysis. The total distance covered (i.e. 20 m x number of completed shuttles) was therefore reported as the player's performance measure in the MST and used in the statistical analysis.

### *Yo-Yo intermittent endurance test (YIET)*

There are two levels of the YIET, with the Level 1 being for recreational players and the Level 2 for trained soccer players. In our preliminary trial with the same group of subjects, all players attained at least stage 11 in the Level 1 test. Consequently the Level 2 test was used for the present study's data collection. The tape (YO-YO tests, HO + Strom, Denmark) was calibrated prior to every trial and procedures were identical to that previously described (Bangsbo, 1996). Two markers were positioned 20 m apart; with another marker 2.5 m behind the start marker. Players ran back and forth (2 x 20 m) in time with the "beep" sounds from the tape. At the end of the 40 m run, players walked or jogged slowly around the marker 2.5 m back to the start point within 5 s. At this point, the player

stopped and waited for the signal for the start of the next shuttle. The successful run of the 40 m (2 x 20 m) distance comprised the completion of a shuttle. The speed for the shuttle runs would progressively increase throughout the test. The player was warned if he did reach the end line on time once and test was terminated when he i) could not follow the set pace of the “beeps” on two separate occasions (note: in contrast to the MST, the two warnings need not be in succession in the YIET) and/or ii) stopped voluntarily. The total distance covered (i.e. 40 m x number of completed shuttles) was reported as the player’s performance measure in the YIET. The 5 m distance covered during the five second recovery periods were not included in the total distance performed by the player during the test (Bangsbo, 1996).

### **Test of running on a treadmill (TRT)**

The TRT trials were conducted in a standardized laboratory environment (temperature and relative humidity were 22-25 °C and 60-65% respectively). Player warmed-up on the treadmill (Venus, HP-Cosmos, Germany) for 3 min at 8.0 km·h<sup>-1</sup> followed by 5 min of self-stretching the lower limbs. The test commenced at 10.0 km·h<sup>-1</sup> and zero gradient for 2 min, followed by an increase to 12.0 km·h<sup>-1</sup> for another 2 min. Thereafter, gradient was systematically increased by 2% every minute until a maximum of 12% was attained. If termination was not achieved by this time, the speed was increased by 1.0 km·h<sup>-1</sup> every minute thereafter until the player attained volitional exhaustion.

During the YIET, MST and TRT trials, players’ heart rate (HR) was continuously monitored with a short-range telemetry HR monitor (S610, Polar Electro OY, Kempele, Finland). HR data was recorded continuously and the average of the highest two consecutive 15 s readings was used as the player’s maximum heart rate (HR<sub>max</sub>) for that trial. Blood lactate concentration ([La]) was obtained via finger-prick within 30 s post-exercise and measured with a lactate analyzer (Accusport, Boehringer Mannheim, Germany).

Eight players (3 defenders, 3 midfielders and 2 forwards) of the 21 players were randomly chosen to

perform their YIET, MST and TRT trials equipped with a reliable and validated ambulatory gas equipment (MetaMax®3X, Cortex Biophysik, Leipzig, Germany) (Larsson et al., 2004). The system comprised the analyzer unit, battery pack, and facemask, which weighs ~1.5 kg and was strapped onto a harness that the player wore over his exercise attire. None of the players had any negative remarks of the system’s weight, and on their mobility and vision during exercise. The analyzers were calibrated according to the manufacturer’s instructions prior to each trial run. Minute ventilation (V<sub>E</sub>), oxygen uptake (VO<sub>2</sub>), expired carbon dioxide (VCO<sub>2</sub>), respiratory exchange ratio (RER) were averaged over 10 s in the mixing chamber mode, with the highest 30 s value (i.e. three consecutive 10 s) used in the analysis. Players were deemed to have attained VO<sub>2max</sub> if any three of the following criteria, as advocated by Davies (1995), were met: i) blood lactate concentration ([La]) during first 5 min of recovery >8 mmol·L<sup>-1</sup>, ii) RER >1.05, iii) HR at termination >95% age-predicted HR<sub>max</sub>, iv) plateau in VO<sub>2</sub> despite increase in running speed or elevation, and v) volitional exhaustion. If not, the trial was repeated for that player on another day. Three subjects were made to repeat one of their three exercise trials. For all the trials, all players satisfied the defined criteria for the attainment of VO<sub>2max</sub>.

### **Statistical analysis**

The SPSS (11.5 for Windows) was used for all statistical analyses. One-way analysis of variance (ANOVA) was used to determine if there were significant differences in the performances and physiological responses in the MST, YIET and TRT. The Pearson product moment correlation coefficient (r) was used to determine the relationship in the players’ performance and selected physiological measures between the three tests. The level of statistical significance was set at p < 0.05.

## **RESULTS**

Table 1 shows the 21 players’ performance data obtained in the MST and YIET. There were

**Table 1.** Performance indicators and physiological responses in the MST (20 m multistage shuttle run test) and YIET (Yo-Yo intermittent endurance Level 2 test) in soccer players (n = 21). Data are means (±SD).

	<b>MST</b>	<b>YIET</b>
<b>Distance covered (m)</b>	2041 (179)*	1676 (314)
<b>Peak speed attained (km·h<sup>-1</sup>)</b>	13.6 (0.4)*	15.7 (0.8)
<b>HR<sub>max</sub> (b·min<sup>-1</sup>)</b>	192 (8)	191 (8)
<b>Post-exercise [La] (mMol)</b>	13.0 (1.6)	13.1 (2.7)
<b>Time to exhaustion in the test (min)</b>	11.2 (0.8)	10.2 (2.7)

\*significantly different from YIET, p < 0.001. Abbreviations: HR<sub>max</sub> = maximal heart rate; [La] = blood lactate concentration.

**Table 2.** Physiological responses in the TRT, MST and YIET in soccer players (n = 8).

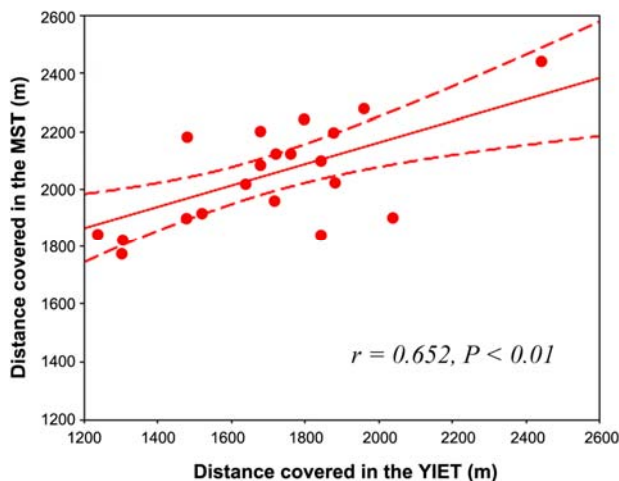
	TRT	MST	YIET
<b>Body mass (kg)</b>	60.8 (8.2)	60.8 (7.7)	60.8 (7.9)
<b>V<sub>E</sub>max (L·min<sup>-1</sup>)</b>	124 (16)	125 (17)	120 (18)
<b>VO<sub>2</sub>max (L·min<sup>-1</sup>)</b>	3.48 (.35)	3.56 (.34)	3.38 (.30)
<b>VO<sub>2</sub>max (ml·kg<sup>-1</sup>·min<sup>-1</sup>)</b>	57.8 (5.0)	59.1 (4.8)	56.1 (4.5)
<b>RER at VO<sub>2</sub>max *</b>	1.16 (.03)	1.10 (.03)	1.05 (.03)
<b>HR<sub>max</sub> (b·min<sup>-1</sup>)</b>	188 (7)	194 (8)	193 (9)
<b>Post-exercise [La] (mMol)</b>	12.3 (3.1)	12.9 (2.3)	12.4 (2.9)

\* TRT > MST > YIET, p < 0.01

Abbreviations : TRT = treadmill run test; MST = 20 m multistage shuttle run test; YIET = Yo-Yo intermittent endurance Level 2 test; V<sub>E</sub>max = maximal minute ventilation; VO<sub>2</sub>max = maximal oxygen uptake; RER = respiratory exchange ratio; HR<sub>max</sub> = maximal heart rate; [La] = blood lactate concentration.

significant differences in the distance covered and peak speed attained during the two field tests. There were no significant differences in the players' HR<sub>max</sub>, post-exercise [La] and time to exhaustion during both tests. There were positive significant correlations in the distance covered (r = 0.65, p < 0.01, Figure 1) and peak speed attained (r = 0.63, p < 0.01) between the MST and YIET.

Table 2 shows the cardiovascular and physiological measures obtained during the MST, YIET and TRT in the eight selected players. Except for RER, there were no significant differences in all other variables among the three tests. The mean differences in the measured VO<sub>2</sub>max between TRT and MST and between TRT and YIET were  $-1.4 \pm 2.6$  and  $1.7 \pm 1.7$  ml·kg<sup>-1</sup>·min<sup>-1</sup>, respectively.



**Figure 1.** Relationship in the distance covered between the 20 m multistage shuttle run test (MST) and the Yo-Yo intermittent endurance Level 2 test (YIET) in trained young soccer players (n = 21). Broken lines represent 95% estimation interval.

Table 3 shows the Pearson correlation matrix between the measured VO<sub>2</sub>max obtained in all the three tests. There were strong positive correlations in the measured VO<sub>2</sub>max among the tests. Table 4 shows the correlations in the distances covered in the two

field tests with the measured VO<sub>2</sub>max obtained in the same field tests and in the TRT for the eight players. There were no significant correlations between performance in the YIET with the measured VO<sub>2</sub>max obtained in all the three test trials. In contrast, there were strong significant correlations between performance in the MST with measured VO<sub>2</sub>max in the same MST and in the YIET; and almost attaining statistical significance with measured VO<sub>2</sub>max in the TRT.

**Table 3.** Correlation coefficient matrix of the measured maximal oxygen uptake (VO<sub>2</sub>max in ml·kg<sup>-1</sup>·min<sup>-1</sup>) between the MST (20 m multistage shuttle run test), the YIET (Yo-Yo intermittent endurance Level 2 test) and the TRT (treadmill run test) in soccer players (n = 8).

	YIET	TRT
<b>MST</b>	.92*	.86*
<b>YIET</b>	-	.94*

\*p < 0.01.

## DISCUSSION

The eight players tested have had similar maximal exercise responses in their MST, YIET and TRT. The magnitude of the mean differences in the measured VO<sub>2</sub>max was small, and within the typical daily variability of <5% or  $\pm 2$  ml·kg<sup>-1</sup>·min<sup>-1</sup> (Katch et al., 1982; Skinner et al., 1999). The mean differences in the measured VO<sub>2</sub>max were also comparably similar between TRT and YIET and between TRT and MST. Thus considering that physiological measures taken in the TRT as the 'gold standard' (Costill, 1967, Saltin and Astrand, 1967), both the YIET and MST were deemed valid field-based tests of maximal aerobic exertion and power in soccer players.

In agreement with the study by Figueiredo et al. (2004), the present study of 21 players found a modest association between the YIET and MST. The two field tests shared a common variance of only

**Table 4.** Correlation coefficient matrix of the performance (i.e. distance covered in metres) in the YIET (Yo-Yo intermittent endurance Level 2 test) and in the MST (20 m multistage shuttle run test) with the measured maximal oxygen uptake ( $VO_{2max}$  in  $ml \cdot kg^{-1} \cdot min^{-1}$ ) in the same YIET and MST as well as in the TRT (treadmill run test), in soccer players ( $n = 8$ ).

	YIET ( $ml \cdot kg^{-1} \cdot min^{-1}$ )	MST ( $ml \cdot kg^{-1} \cdot min^{-1}$ )	TRT ( $ml \cdot kg^{-1} \cdot min^{-1}$ )
YIET (m)	.67	.55	.48
MST (m)	.74*	.80 *	.68 †

\* $p < 0.05$ ; †  $p = 0.06$

40% indicating that performance in either test may not be interchangeable. The reason for the low association observed between the MST and YIET performances could largely be attributed to the subtle, but probably, physiologically significant differences in the tests' protocols. Firstly, the YIET commenced (i.e.  $11.5$  vs.  $8.0$   $km \cdot h^{-1}$ ) and terminated (see Table 1) at higher running speeds. The higher running speeds throughout the YIET has led to anecdotal suggestion that the player's anaerobic system was being utilized to a greater extent in the YIET as compared to that in the MST (Lemmink et al., 2003). Nevertheless, similar post-exercise blood [La] in both test trials observed in the present study did not appear to support this assertion. Secondly, there was a five seconds rest interval after every 40 m shuttle ran that was deemed to provide some form of recovery in-between the high-intensity shuttle runs (Bangsbo, 1996). We speculate that these recovery periods might be the main cause for the physiological responses during the YIET to differ from that of the MST. For example, Christmass et al. (1999) compared two exercise protocols of continuous- (i.e. akin to the MST) and intermittent-type (akin to the YIET), at an equivalent intensity of 70%  $VO_{2max}$ . They found that the latter oxidized significantly greater amount of carbohydrate and had a lower relative oxygenation at the skeletal muscle level which seemed to indicate a marked difference in the metabolic and oxygenation response within the same subject when exposed to these two contrasting types of exercise protocols of equivalent intensity, at least at the submaximal level (Christmass et al., 1999). Another recent study showed that the performance during the Interval Shuttle Run, a field-based test which possesses similar intermittent running protocols as the YIET, was able to clearly distinguish varying levels of competitiveness in soccer players; but not the MST (Lemmink et al., 2004). Taking into consideration these findings as well as the findings from the present study, it is plausible that the performance in the YIET may be measuring slightly different aspect(s) of the athlete's endurance fitness and/or performance. The MST protocol is by nature continuous whilst the YIET is principally intermittent. It is noteworthy that the "run-pivot-run-

recovery-stop-run" nature of the YIET replicates more closely soccer match-play movements than the "run-pivot-run" nature of the MST (Bangsbo, 1996). Thus, it seems reasonable to suggest that the YIET characterizes an athlete's endurance performance that is predominantly "intermittent" in nature whilst the MST may be more ideal for the assessment of endurance performance that is performed "continuously".

Although there were strong relationships in the measured  $VO_{2max}$  among the three tests, in practice coaches would be more concerned with the absolute performance measure attained in the field tests (i.e. distance covered during the YIET and MST since this directly reflect the player's level of endurance capability) rather than the players' oxygen uptake. In this regard, the present study revealed several interesting observations. Firstly, performance in the MST was associated with the measured  $VO_{2max}$  obtained in the two field tests and almost reaching statistical significance in the TRT. But there was no relationship in the players' performance in the YIET with the players' measured  $VO_{2max}$  obtained in the same YIET as well as with the measured  $VO_{2max}$ , obtained either in the MST or in the TRT. These findings suggest that, relative to the MST, the performance in the YIET has little relationship with the typical determinants of  $VO_{2max}$  (for example, level of oxidative enzymes and red cell mass, mitochondrial size and numbers, capillary) (see Noakes, 1997 and 2000).

Our data support observations of similar studies in soccer players. For example, Castagna et al. (2003) found no correlation between youth-level players' performance in the YIET with their measured  $VO_{2max}$  in the TRT as well as in the same YIET ( $r = 0.47$  and  $r = 0.51$ , all  $p > 0.05$ ,  $n = 18$ , respectively). Similarly, Bangsbo et al. (1992) found no correlation between measured  $VO_{2max}$  obtained during the TRT and a prolonged soccer-specific intermittent endurance test among professional players ( $r = 0.18$ ,  $p > 0.05$ ,  $n = 8$ ). Taking together the view that YIET is an acceptable field-based measure of the soccer players' intermittent endurance performance as well as the lack of association between performance in the YIET with all the measured  $VO_{2max}$  values, it might

alternatively be argued that measured  $\text{VO}_{2\text{max}}$  per se, obtained during either the traditional treadmill run or even during soccer-specific field tests, cannot fully explain nor characterize soccer players' intermittent endurance performance (Bangsbo and Lindquist, 1992; Oliveira et al., 2001b). This observation is not surprising since the original intent of the MST was designed to predict the participants'  $\text{VO}_{2\text{max}}$  (Léger and Lambert, 1982; Ramsbottom et al., 1988), whilst the YIET was fundamentally developed to assess the team sports player's "ability to repeatedly perform intervals over a prolonged period of time" (Bangsbo, 1996, p. 16). The YIET was purely concerned with performance per se and there was no deliberate effort by the test's creator to estimate the player's  $\text{VO}_{2\text{max}}$  from the performance obtained during the test (Bangsbo, 1996).

Thus overall, the collective evidence from the present study seems to suggest that the YIET may be a more favourable field-based test of soccer player's endurance performance as compared to the MST.

As a pilot investigation, a major limitation of the present study is its small sample size. In statistical correlation analyses, a high correlation value is typically obtained with a sample of heterogeneous subjects. In the present study however, our subjects possessed homogenous characteristics. Subjects were from one sport-type and were randomly selected from a single squad, the country's best youth talent. The players were of similar age and physical characteristics, and have been undergoing the same training regimen for the past four months. The subjects' performance in the field tests and their measured  $\text{VO}_{2\text{max}}$  values would categorize them as well-trained soccer players (Aziz et al., 2004; Bangsbo, 1996; Tumilty, 2000). Therefore, given these characteristics of this small sample size, the statistical findings were noteworthy observations. Nevertheless, extra caution is clearly warranted when interpreting the present study's findings until confirmatory studies with more subjects are obtained.

## CONCLUSIONS

This pilot investigation found that the physiological variables and measured  $\text{VO}_{2\text{max}}$  of soccer players obtained in the YIET and MST were comparably similar to that obtained in the TRT indicating that both are valid field-based tests of maximal aerobic exertion. However, the lack of association between distance covered in the YIET with all the measured  $\text{VO}_{2\text{max}}$  values suggest that measured  $\text{VO}_{2\text{max}}$  per se may not be suitable to characterize soccer players' intermittent endurance performance. In comparison with the MST, the YIET may also be a more

favourable field-based assessment of soccer player's endurance performance.

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**KEY POINTS**

- Both the Yo-Yo intermittent endurance test and 20m multistage shuttle run test are valid measures of aerobic exertion in soccer players
- Measured  $\text{VO}_{2\text{max}}$  per se may not be suitable to characterize soccer players' intermittent endurance performance.
- In comparison with the MST, the YIET may be a more favourable field-based assessment of soccer player's endurance performance.

**✉ Abdul Rashid Aziz**

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