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Playing Surface Impacts Yo-Yo Intermittent Recovery Test (Level 1) Performance and Validity of Indirect VO2max Estimation

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Abstract

International Journal of Exercise Science 18(8): 1142-1150, 2025. https://doi.org/10.70252/PGPL8156 This study compared performance on the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) and the agility t-test between two playing surfaces, artificial turf and natural grass. This study also assessed agreement between estimated VO2max from the YYIR1 on artificial turf and natural grass with laboratory measured VO2max. Male collegiate soccer players completed three experimental sessions on separate days: YYIR1 and t-test on artificial turf, YYIR1 and t-test on natural grass, and a laboratory VO2max test. The validated Bangsbo et al. equation was used to estimate VO2max from YYIR1 distance. Participants covered more distance (2370 ± 662 vs. 1441 ± 463 m, $p < .001$) and reached higher maximal aerobic speed (17.29 ± 0.99 vs. 15.76 ± 0.78 km/h, $p < .001$) on natural grass. Agility t-test was faster on grass (8.75 ± 0.53 vs. 9.43 ± 0.73 s, $p < .001$). Grass estimated VO2max was higher than laboratory VO2max and turf estimated VO2max (58.0 ± 4.5 vs. 54.2 ± 3.4 vs. 49.8 ± 3.4 mL/kg/min, $p < .001$). Grass estimated VO2max was positively correlated with turf estimated VO2max ($r = 0.91$, $p < .001$). Bland-Altman analysis indicated that grass estimated VO2max overestimated laboratory VO2max and turf estimated VO2max underestimated laboratory VO2max ($p < .001$). Findings indicate playing surface is a critical factor in the performance outcome and accuracy of field-based aerobic fitness assessment. Findings emphasize the importance of considering environmental and contextual variables when administering and interpreting assessment data.

Keywords: Aerobic capacity, artificial turf, natural grass, YYIR1

Introduction

Aerobic capacity and agility are critical components of performance in field-based sports like soccer, where quick directional changes, short bursts of speed, and sustained endurance define success. As the physical and tactical demands of soccer continue to evolve, the importance of accurate and reliable fitness testing grows. One emerging factor in this domain is the influence of playing surfaces—specifically, artificial turf versus natural grass—on athletic performance outcomes.

Soccer players frequently alternate between artificial turf and natural grass surfaces for practice and competition. The surfaces differ significantly in texture, firmness, and traction, which has been reported to affect both movement efficiency and physiological exertion during matches.[1,2] Andersson et al[1] found that athletes achieved similar distances and intensities on artificial turf and natural grass during matches. However, they also reported negative athlete impressions of the artificial turf and higher perceived physical effort while playing on artificial turf. These findings were supported by Modric et al[2] in which playing on artificial turf was more physically demanding than playing on natural grass. In their study, athletes covered more distance, sustained more moderate and high intensity running, and experienced more accelerations and decelerations on the artificial turf. Nedelec et al[3] matched physiological demand of a soccer match with a 90-minute aerobic field test on artificial turf and natural grass surfaces. In their findings artificial turf did not induce greater fatigue compared to natural grass, however the absence of contact actions, jumps, and tackles that occur in a match may have contributed to their conflicting findings.

Few studies have compared performance on speed and agility assessments between artificial turf and natural grass. No apparent differences between surfaces have been observed in straight sprint speed.[4,5] Artificial turf appears to favor change of direction and agility assessments. Gains et al[4] reported faster agility times in the pro-agility test on artificial turf. Choi et al[6] reported better sprinting and turning performance in speed and change of direction assessments on artificial turf. Ammar et al[7] reported greater distance covered and less of a decline in distance covered during a 6 x 30 second repeated sprint ability test on artificial turf compared to natural grass. The athletes reported lower perceptions of effort and measured lower blood lactate levels on artificial turf. These preliminary findings suggest a benefit of artificial turf for change of direction assessments, but not for linear sprint speed.

A test that is used worldwide in college athletics to assess aerobic fitness that uses a combination of aerobic endurance running and change of direction is the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1). The YYIR1 is a valid, reliable, and practical measurement of soccer-specific endurance capacity.[8–10] While established protocols dictate the test to be administered on an indoor wooden surface, soccer teams regularly administer the test on artificial turf and natural grass during practices. Differences in playing surface have been hypothesized to impact mechanics of running that affect energy requirements of running. The metabolic cost of running on artificial turf and natural grass exceeds the metabolic cost of running on hard surfaces.[11] Additionally, Di Michele et al[12] reported higher heart rate and blood lactate values during a multistage running test on artificial turf compared to natural grass. It is not yet known what effect administering the YYIR1 on different playing surfaces has on assessment results or the ability of the test to estimate VO2max. If changing the playing surface for the athletes could influence the test outcomes, this raises important considerations for athlete assessment protocols.

The purpose of this study was twofold: (a) to investigate whether playing surface impacts aerobic fitness and agility field assessment results and (b) to assess whether performing the YYIR1 on different playing surfaces influences the test's ability to indirectly estimate VO2 max. The authors are not aware of any studies that have directly compared YYIR1 performance or predictive ability of VO2max for the test on different playing surfaces. We hypothesized that (a) athletes would cover less distance in the YYIR1 and would have faster agility t-test times on artificial turf, and (b) performing the YYIR1 on artificial turf would underestimate an athlete's measured VO2max.

Methods

Participants

A priori power analysis was run using GPower (version 3.1.9.7) with a desired power level of 0.80, an alpha level of 0.05, and an effect size of 0.50. The analysis recommended a sample size of 34 participants. Thirty-six participants completed the first part of the study. Twenty-three participants completed the second part of the study. Participants were NCAA Division II collegiate male soccer players (20.0 ± 1.2yr, 1.77 ± 0.05 m, 74.6 ± 7.6 kg, 8.7 ± 3.3% body fat). All participants were cleared for participation by the athletic training staff. Participants were ineligible for study participation if they sustained injuries or were under return to play protocols. Goalkeepers were excluded from the study. This study was approved by the university Institutional Review Board and all participants read and signed consent forms prior to study participation. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[13]

Protocol

Data was collected on three separate days with a recovery period of at least one week between aerobic fitness tests. On day one of the research testing the participants met on an artificial turf field to perform the YYIR1 and the agility t-test. On the second day of research testing participants met on a natural grass field to complete the YYIR1 and agility t-test. Outdoor tests on artificial turf and natural grass surfaces were performed at the same time of day under similar environmental conditions. On day one, the temperature was 23.9 C, humidity was 94%, wind was 0 mph, and pressure was 761.2 mmHg. On day two, the temperature was 22.8 C, humidity was 100%, wind was 0 mph, and pressure was 766.8 mmHg. All participants were familiar with the YYIR1 and agility t-test prior to testing. Both assessments were regularly used by team coaching staff during training to evaluate physical fitness, which ensured returning athletes were familiar with the assessments. New athletes were asked whether they had completed the tests previously, to which all responded yes. Prior to the administration of each fitness test, the researchers thoroughly explained the protocols and provided an opportunity for the athletes to ask questions about the protocols.

The YYIR1 is a valid, reliable test that assesses an athlete's ability to perform repeated intense exercise and recover quickly, while stimulating stop and go sports such as soccer.[8–10] According to the established testing protocol, two sets of cones were set up 20 m apart. The athletes then followed audio cues that indicated when to start and stop running. After each 20m run, there was a 10 second active recovery period. The speed increased incrementally throughout the test, until athletes could no longer maintain the set pace. The athletes were all allowed one "error" throughout their run if they were to miss a pace. VO2max was estimated from the total distance covered in the YYIR1 test using the previously validated Bangsbo et al[14] equation: VO2max = YYIR1 distance (m) x 0.0084 + 36.40.

After performing the YYIR1 test, the athletes completed the agility t-test. While this test is labeled an agility test, the test primarily assesses change of direction due to the absence of a stimulus during the test protocol. When performing the agility t-test, four cones were set up in a “T” shape pattern (10 yards apart for the top of the T and 5 yards for each side). Our participants started at the bottom cone, sprinted quickly to the middle top cone, shuffled out to the right, shuffled back to the middle, then shuffled to the left, back to the middle and then ran backwards to the cone they started at. This process was hand timed with a stopwatch and each participant's scores were recorded.

On the third day of research testing, athletes reported to the lab to complete body composition and VO2max assessment. The Bod Pod (COSMED, Concord, CA) was used to assess body composition. The Bod Pod uses air displacement plethysmography to determine body composition. It measures the athletes’ body volume and weight to calculate body density and estimate body fat percentages. The VO2max test was performed on a treadmill with a starting speed of 9km/h at 0% incline and progressively increased speed 1 km/h every minute until the treadmill reached the top speed of 19 km/h. After the treadmill reached top speed then the treadmill incline progressively increased by 1.5%. The test ended when participants reached volitional fatigue. A metabolic cart was used to measure expired air (ParvoMedics TrueOne 2400, Sandy, UT). All participants were verbally encouraged to give maximum effort. Maximum effort was confirmed through the following criteria: a VO2 plateau, a RER greater than or equal to 1.10, a maximum heart rate greater than or equal to 95% of age predicted maximum, and RPE greater than or equal to 8 on the Borg 0-10 scale.

Statistical Analysis

Descriptive statistics (mean ± SD) were calculated for all outcome variables. Data was checked for normality using histograms and the Shapiro-Wilk test. Data was checked for outliers using z-scores. Paired t-tests were used to compare YYIR1 performance and agility t-test performance between playing surfaces (artificial turf and natural grass). Effect size was calculated as Cohen’s *d* and interpreted as: small = 0.2 to 0.5, moderate = 0.5 to 0.8, large = greater than 0.8. Repeated measures ANOVA was used to compare measured VO2max and estimated VO2max on turf and grass surfaces. Effect size was calculated as partial eta squared (n_p^2). Pearson’s r was used to determine correlations between outcome variables. Values were interpreted as: ≤ 0.1, trivial; 0.1 - 0.3, small; 0.3 - 0.5, moderate; 0.5 - 0.7, large; 0.7 - 0.9, very large; and > 0.9, almost perfect. Bland-Altman plots were used to examine differences between estimated VO2max on each playing surface with measured VO2 max. Statistical significance was set at 0.05. Statistical analysis was performed using JASP version 0.19.3.0.

Results

Results indicated a statistically significant difference in performance across playing surfaces. More distance was covered on the grass (M = 2370 m, SD = 662 m) than on the turf (1441 m, SD = 463 m), $t(35) = -17.2$, $p < .001$, $d = 2.87$. Additionally, a statistically higher maximal aerobic speed was achieved on the grass (M = 17.25 km/h, SD = 0.99) compared to the turf (M = 15.76 km/h, SD = 0.78), t(35) = -17.8, p < .001, d = 2.97. A paired t-test for agility t-test performance revealed a significant difference, with faster times recorded on grass (M = 8.75 s, SD = 0.53) compared to turf (M = 9.43 s, SD = 0.73), t(35) = 5.0, p < .001, d = 0.84. Repeated measures ANOVA indicated a statistically significant difference between laboratory measured VO2max, turf estimated VO2max, and grass estimated VO2max, F(2,1.31) = 70.04, p < .001, n_p^2 = 0.761. Post hoc tests revealed each measure differed from the others (p < .001). Grass estimated VO2max was the highest (58.0 ± 4.5 mL/kg/min), followed by measured VO2max (54.2 ± 3.4 mL/kg/min), and then turf estimated VO2max (49.8 ± 3.4 mL/kg/min).

There were moderate positive correlations between grass estimated VO2max (r = 0.48, p = .02) and turf estimated VO2max (r = 0.53, p = .008) with laboratory measured VO2max. There was an almost perfect positive correlation between the grass estimated VO2max and turf estimated VO2max (r = 0.91, p < .001). The Bland-Altman plots showed that the grass estimated VO2max significantly overestimated measured VO2max (Figure 1; p < .001). The mean difference was 3.8 with 95% limits of agreement between 12.0 to -4.5. The Bland-Altman plots showed that the turf estimated VO2max significantly underestimated the measured VO2 max (Figure 2; p < .001). The mean difference was -4.4 with 95% limits of agreement between 2.2 to -11.0.

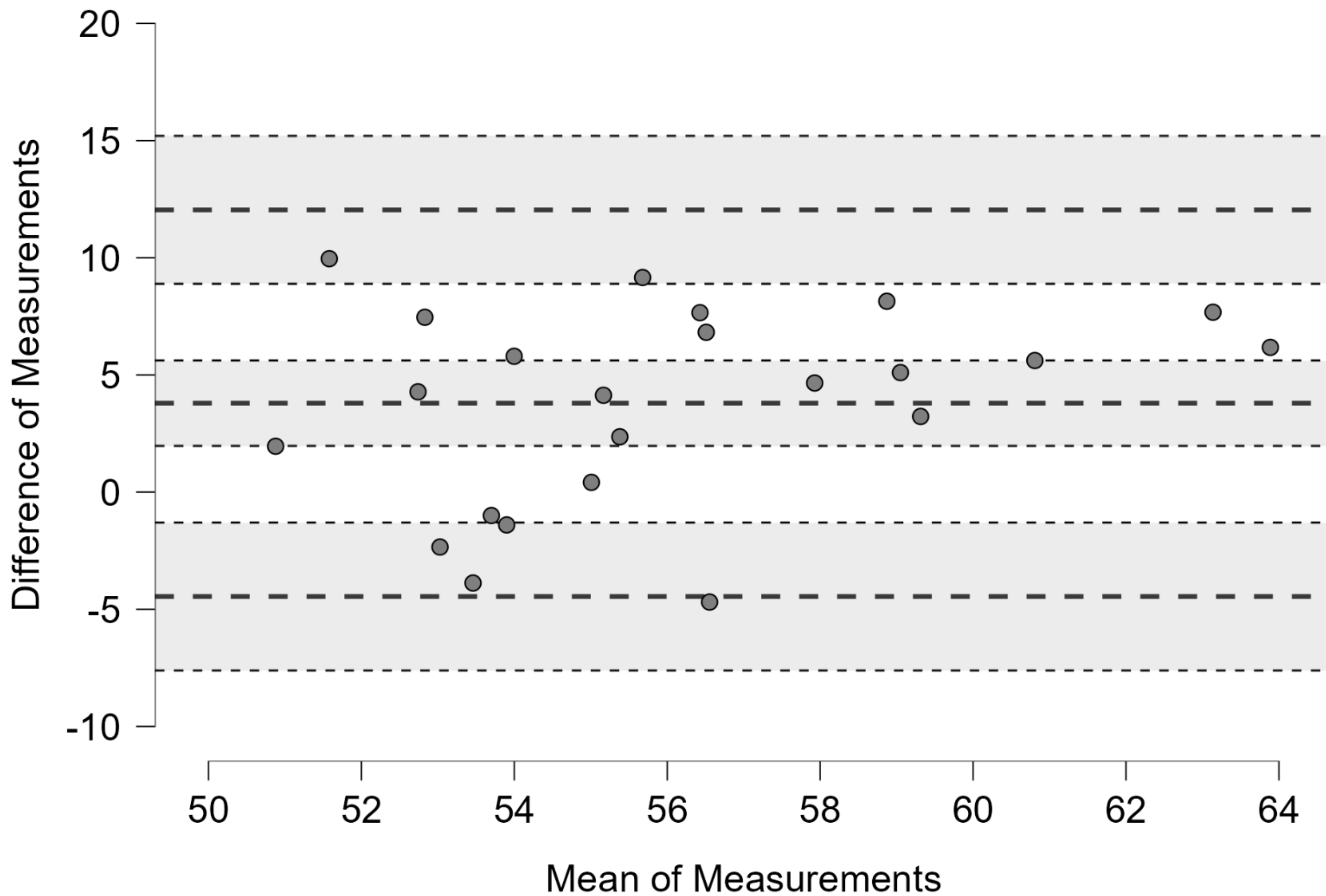

Figure 1. Bland-Altman plots for estimated grass VO2max and laboratory VO2max

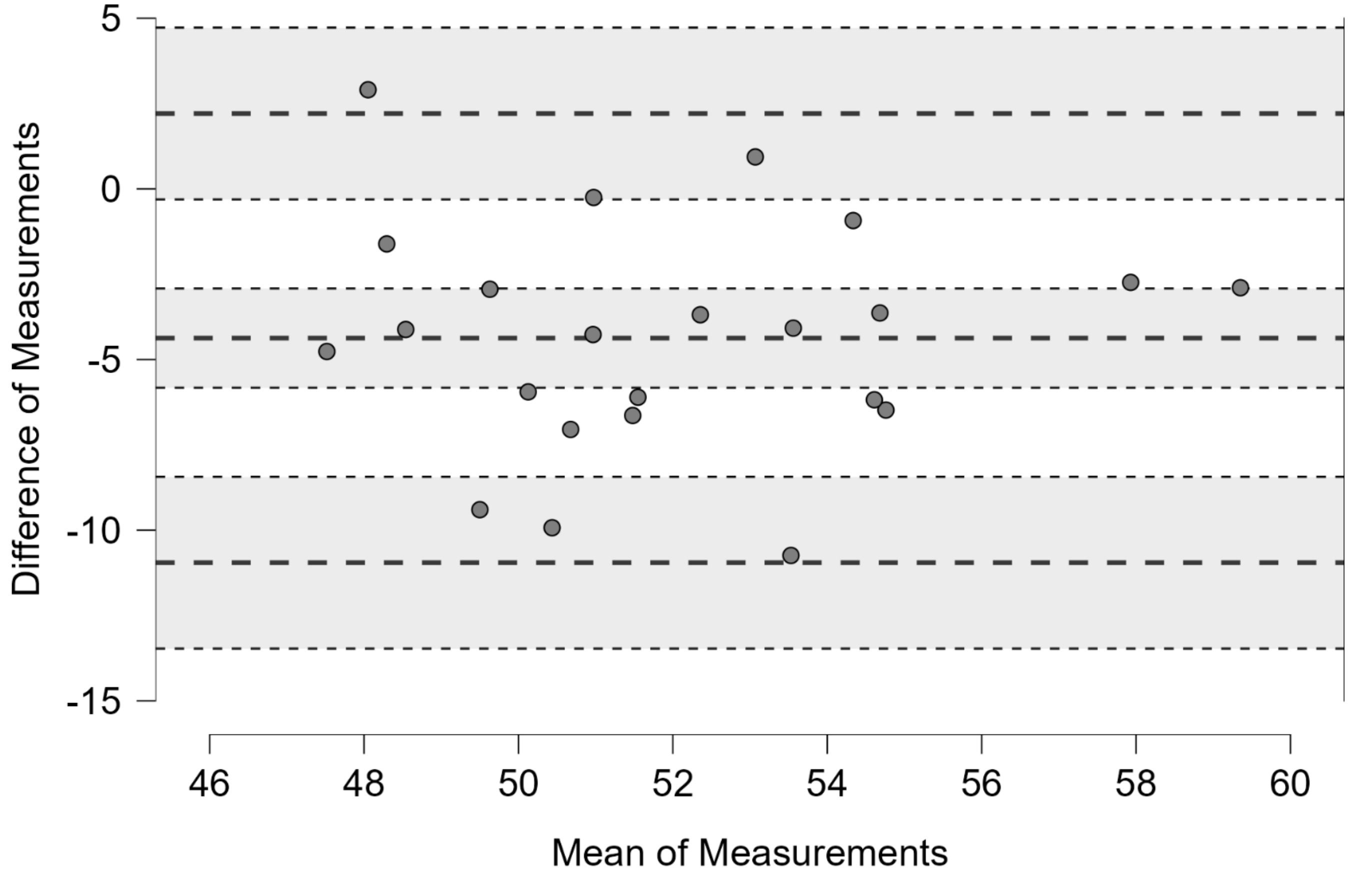

Figure 2. Bland-Altman plots for estimated turf VO2max and laboratory VO2max

Discussion

The purpose of study (a) was to investigate whether playing surface impacts aerobic endurance and agility field assessment results. Our results conclude that natural grass provides a superior playing surface for both agility and aerobic endurance assessment performance compared to artificial turf. In agreement with our hypothesis, athletes covered more distance and ran at higher speeds while performing on natural grass. In contrast to our hypothesis, agility times were also faster on the natural grass. There was a strong relationship between VO2max estimations on the natural grass and the artificial turf playing surfaces and a moderate relationship between estimated VO2max with measured VO2max. The purpose of study (b) was to assess whether performing the YYIR1 on different playing surfaces influenced the test's ability to predict VO2max. Our hypothesis was partially supported. Our analysis showed that performing the YYR1 on grass overestimated the athlete's laboratory measured VO2max, while the artificial turf underestimated laboratory measured VO2max.

While the authors are not aware of any studies that directly align with the methods of our study, there is research that describes similar topics to the research findings. Our study examined an aerobic endurance field assessment (YYIR1) with high demands on both aerobic and anaerobic energy systems that incorporates a change of direction component. Previous research supports a benefit for change of direction performance but greater metabolic demands and physical effort of running on artificial turf. Our findings contradict previously reported change of direction and agility findings on artificial turf.[4,6,7] However, our finding of less distance covered and slower maximal aerobic speed on the artificial turf compared to the natural grass supports prior findings of an increased physiological demand of running on artificial turf.[2,12] Higher blood lactate levels and higher heart rates have been found at running speeds up to 14 km/h on synthetic turf compared to both natural grass and laboratory treadmill running.[12] It is possible these physiological effects could lead to earlier volitional fatigue in the YYIR1 on artificial turf. For comparison, our athletes reached maximal aerobic speeds of 17.25 km/h on the natural grass and 15.76 km/h on the artificial turf. Additionally, Andersson et al[1] reported that players had a negative impression of artificial turf and felt that the surface required more physical effort, despite no differences in physical demands of the task. Players who experience similar impressions and perceptions on artificial turf could experience a negative effect on effort and motivation on the physically demanding task, reducing their drive to complete the task to volitional fatigue. The previously reported findings in soccer-specific situations could help explain why athletes performed worse in the YYIR1 on artificial turf in this study.[1,2]

Two prior studies found no differences in performance between artificial turf and natural grass.[3,11] Sassi et al[11] found that the energy cost of running was similar between natural grass and artificial turf. A limitation to applying those findings to the YYIR1 is that the running speeds used in the study were at steady-state speeds below the anaerobic threshold (8, 10, and 12 km/h). For reference, the YYIR1 exceeds 12 km/h by the third 2 x 20 m run of the test. The YYIR1 is an incremental test to exhaustion that maximizes both the aerobic and anaerobic energy systems.[9] It is possible that differences in the metabolic cost of running may appear at higher speeds, and when anaerobic metabolism makes a greater contribution, which limits the applicability of these findings to the demands of the YYIR1. Additionally, a 90-minute aerobic soccer-specific training session found no differences in physiological intensity or fatigue between playing surfaces.[3]

While there was a discrepancy in YYIR1 performance outcome results on artificial turf and natural grass (total distance covered and maximal aerobic speed), the strong positive correlation indicated that players who covered more distance on the YYIR1 on artificial turf also covered more distance on natural grass, while athletes who covered less distance on the artificial turf were also likely to underperform on the natural grass. For practitioners, the key takeaway from this relationship is that regardless of the testing surface, the YYIR1 assessment can identify top performers and low performers. However, due to the discrepancy in distance covered between playing surfaces, coaches should standardize a testing surface to monitor individual athlete progression.

Our results revealed moderate correlations between YYIR1 estimated VO2max and measured VO2max and an inconsistency in the ability to predict VO2max from different playing surfaces. Previous studies report mixed findings about correlations between VO2max and YYIR1 performance. Several studies[9,14] report a strong relationship between YYIR1 distance and VO2max, while other studies[15,16] report small to moderate relationships. Our study found moderate correlations with YYIR1 performance and VO2max on the artificial turf and on the natural grass. Bangsbo et al[14] found that despite a strong relationship between YYIR1 distance and VO2max in their study, there were varied YYIR1 results for the same VO2max values, indicating estimation of VO2max from the YYIR1 was not accurate. The Bland-Altman analysis in our study revealed similar conclusions on both the artificial turf and the natural grass conditions. Our findings are in agreement with prior studies that documented a significant relationships between YYIR1 performance and VO2max, but reported discrepancies between YYIR1 performance and ability of the test to estimate VO2max.[14,17] Unique to our findings is the discrepancy in VO2max estimation from each playing surface.

There were some limitations with this study. The first limitation is the order of the experimental sessions was not randomized. This was due to the practice and competition schedule of the athletes and the scheduling of the practice facilities. All participants ran on the artificial turf first and the natural grass second, which could have influenced the results. The participants were familiar with the tests, but we could not control their motivation and work ethic. Another limitation is that while 36 participated in part (a) for the YYIR1 tests, only 23 participants returned to the laboratory for VO2max testing in part (b). This was because of illness, injury, and compliance paperwork issues. There was also a limitation in the order of testing for the YYIR1 and the agility t-test. This study administered the YYIR1 before the agility t-test, which may impact t-test results due to fatigue from the previous YYIR1 test. This may also limit the ability to relate this study's t-test scores to other studies which administered the assessment earlier in the testing battery.

This study addresses a previously underexplored area of how different playing surfaces (natural grass and artificial turf) can impact performance outcomes in field-based fitness assessments. To guarantee consistency and fairness in athlete evaluation, sports teams should use standardized testing settings to eliminate the effect of playing surface on testing outcomes. Our findings advocate that surface type is a critical factor in the accuracy of aerobic fitness assessments. By identifying the discrepancies between estimated and laboratory VO2max values across different playing surfaces, this research highlights the importance of considering environmental and contextual variables when evaluating athlete performance. These findings can also be used by facilities in conjunction with research on playing surface injury risks to guide decisions about artificial turf vs natural grass field installations. Future research in this area should examine the effect of playing surface on different physical fitness tests, and the underlying physiological or biomechanical differences during the performance of the tests.

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