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**Research Article / Araştırma Makalesi**

# Investigation of the relationship between lower extremity functional performance of American football players and their anthropometric characteristics and jump test results

## *Amerikan futbolu oyuncularının alt ekstremite fonksiyonel performansları ile antropometrik özellikleri arasındaki ilişkinin ve hop testi sonuçlarının incelenmesi*

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**ABSTRACT**

**Objective:** Hop tests have well-known benefits when evaluating the rehabilitation process after sports injuries. However, utilization of hop tests to evaluate functional athletic performance of healthy athletes is currently uncertain and is not common in clinical practice. This study aimed to investigate the relationships between hop performance, their symmetries and functional test performance in American Football (AmF) players.

**Materials and Methods:** Twenty-six collegiate AmF players aged 20.9±2.5 years participated in this study. According to their playing positions, players categorized as Skill Players (SP), Big Skill Players (BSP) and Linemen (LM). Body Mass Index (BMI) and body fat ratio were measured. Then, subjects were performed hop tests and 10-yards Lower Extremity Functional Test (LEFT). Players were also analysed by dividing into low and high performers for LEFT, according to their LEFT test duration.

**Results:** Hop test performance of the SP was superior to LM for SLH, TH, and CH. The performance of BSP was inferior to SP for CH, and was superior to LM for SLH. In LEFT, the SP group was significantly faster than LM. For LEFT, TH, CH and 6H test results were significantly different between low and high performer players.

**Conclusion:** Hop tests may be utilized to evaluate the functional athletic performance of AmF players. Physical characteristics and playing positions should also be considered. Symmetry had no effect on LEFT.

**Keywords:** *Football, hop test, asymmetry, playing position, speed, agility*

**ÖZ**

**Amaç:** Hop testlerinin spor yaralanmaları sonrası rehabilitasyon sürecini değerlendirirken sağladıkları yararları bilinmektedir. Bununla birlikte hop testlerinin, sağlıklı sporcuların fonksiyonel atletik performansını değerlendirmek için kullanımı net değildir ve bu alandaki klinik uygulamalarda yaygın değildir. Bu çalışmayla, Amerikan Futbolu (AmF) oyuncularında sıçrama performansı, simetrileri ve fonksiyonel test performansı arasındaki ilişkileri araştırmak amaçlandı.

**Gereç ve Yöntemler:** Bu çalışmaya yaşları 20.9 ± 2.5 olan 26 üniversiteli AmF oyuncusu katıldı. Oyuncular oynadıkları pozisyonlara göre Beceri Oyuncuları (SP), Büyük Beceri Oyuncuları (BSP) ve Çizgi Oyuncuları (LM) olarak kategorize edildi. Katılımcıların Vücut Kütle İndeksi (VKİ) ve vücut yağ oranı ölçüldü. Ardından katılımcılara hop testleri ve 10 yard Alt Ekstremite Fonksiyonel Testi (LEFT) uygulandı. Oyuncular aynı zamanda LEFT testi bitirme sürelerine göre yüksek ve düşük performans gösterenler olarak ikiye ayrılarak analiz edildi.

**Bulgular:** SP'nin hop testi performansı SLH, TH ve CH için LM'den üstündü. BSP'nin performansı CH için SP'den daha düşüktü ve SLH için LM'den daha üstündü. LEFT'de, SP grubu LM'den anlamlı düzeyde daha hızlıydı. LEFT için yüksek ve düşük performans gösterenler arasında , TH, CH ve 6H test sonuçları anlamlı düzeyde farklıydı.

**Sonuç:** AmF oyuncularının fonksiyonel atletik performansını değerlendirmek için hop testleri kullanılabilir. Fiziksel özellikler ve oyun pozisyonları da dikkate alınmalıdır. Simetrinin LEFT üzerinde hiçbir etkisi bulunmamıştır.

**Anahtar Sözcükler:** *Futbol, hop testi, asimetri, oyun pozisyonu, hız, çeviklik*

## INTRODUCTION

American football (AmF) is a recently improving sport in Türkiye with a history of only about 30 years (1). The official Turkish Protected Football League was founded in 2005 (2). The global origins of AmF go back to a game played between two college teams in the United States of America in the 1860s. The official National Football League was founded in

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1920 and AmF has become one of the most popular sports in the USA. The popularity of AmF encourages American athletes to get involved with this sport starting from early ages. Contrarily, in Türkiye where the sport is still in its infancy, most Turkish athletes are introduced to this sport when they go to college and learn about its athletic properties. Therefore, the starting age for AmF in Türkiye is quite high compared to countries in which AmF is popular. As a result of the late starting age in Turkish AmF players, players are more likely to be divided into playing positions according to their anthropometric features instead of position specific skills. Based on the evidence that increasing experience and time spent in the sports branch lead to improvement of athletes' sport-specific techniques and are also important factors for preventing sports injuries (3–5), the advanced starting age may bring undesired outcomes for athletes.

In previous reports, sports injuries mostly occur in the lower extremities (6,7). Common game characteristics and movement patterns of different sports branches may increase the injury risk, such as deceleration, acceleration, change of direction, and contact with an opponent (3). Therefore, AmF has one of the highest injury prevalence among sports, since the game characteristics not only require the athletes to perform high risk movements, but also expose the athletes to possible contact, tackles and collisions from their opponents (7). For this risky sport, the lack of experience of the athletes also contributes to the risk of injury. Therefore, it is highly important to include interventions to reduce the injury risks for these athletes. Since the most common injuries occur in the lower extremities, identifying injury risk factors in athletes and targeting these detected factors should be considered when planning injury prevention strategies. While impaired dynamic balance, strength and functional movements are known as factors that increase injury risk (8), achieving symmetry for these skills is also a major consideration for injury prevention, treatment and safe return to sports (9).

Despite being frequently used to evaluate lower extremity functions in the recovery period after injuries such as anterior cruciate ligament reconstruction (9), hop tests that mimic common athletic movements with jumping and landing movements can also be utilized to evaluate lower extremity strength and balance performances, and also their symmetries (10,11). It is known that measurable asymmetries may found in non-injured athletes, and not necessarily lead to performance impairments (12). This means that, despite hop tests providing valuable information about different aspects of performance and limb symmetry, it may not be sufficient to evaluate these tests apart from functional sport specific performance tests, containing combined functional movements aiming to simulate the performance in real sports events as closely as possible.The 10-yards Lower Extremity Functional Test (LEFT) evaluates sprint, backpedal, shuffle and carioca runs that are similar functional movements and distances that need to be covered to score in a regular AmF match, and is considered an inexpensive, portable, and easily administered test for AmF performance. Therefore, we aimed to investigate the relationships between hop performance, their symmetries and lower extremity functional test performance. Additionally, since there are no data in the **national** literature, we also aimed to report the performance profiles of Turkish AmF athletes. We hypothesized that *i)* player anthropometrics will affect hop and LEFT test performances; higher BMI and BF will lead to lower performance, *ii)* different playing positions will lead differences in hop and LEFT test performances, *iii)* athletes who have better LEFT performance will also have better hop test performances, and *iv)* athletes with asymmetries in hop tests will have lower LEFT performance.

## MATERIAL and METHODS

### Study Design

The study was designed as a cross-sectional study. Test performances, side to side asymmetry, and their relationship were investigated. The tests were conducted over two sessions, separated by 24 hours. In the first session, information about characteristics (age, playing position, history of prior or present injury or chronic illness, medication use) was collected, and weight, height, body mass index, and body fat ratio were measured. 24 hours after the anthropometric measurements, hop tests and LEFT were performed as the second session. Subjects were informed not to exercise at least 24 hours, and not to drink alcohol, smoke, and consume food or drinks containing caffeine. In order to eliminate the possible effect of shoe designs and the support they provide on individual performance, participants are asked to wear their personal athletic clothes and footwear (13). Tests were performed in the training field of AmF teams, which the ground is natural turf, and at the time of their regular training which is at 8 PM. Prior to tests, subjects were performed a standard 10-minute warm-up at 60% of their personal perceived exertion. Rest period was set to 3 minutes between the tests (14).

### Subjects

A total of 26 collegiate American football players participated in this study. The players had a mean age of 20.9 years (range 18–28, SD 2.5 years). Their mean height was 181.5 cm (range 171–195, SD 6.3), body weight was 89.5 kg (range 67–125.2, SD 16.2), body mass index (BMI) was 27.2 kg/m$^2$ (range 19.4–39.5, SD 1.9) and body fat ratio was 15.0% (range

4.1–28.5, SD 6.8). Players were also categorized into three groups according to their playing positions: Skill Players (SP), Big Skill Players (BSP) and Linemen (LM) based on Sierer et al.'s study as fullbacks, linebackers, tight ends, and defensive ends were categorized as BSP. Centers, offensive guards, offensive tackles, and defensive tackles were categorized as LM (15). Eight players (30.8%) were SP, 9 players were BSP (34.6%) and 9 players were LM (34.6%).Exclusion criteria were: leg length discrepancy >2 cm, acute lower extremity injury (within 2 weeks), self-reported neuromuscular disorders and neurological, orthopaedic, vestibular or any other disorders that could affect athletic performance. All participants were informed about the testing procedures and gave written informed consent for participation in the study. The study was approved by an institutional review board and conducted according to the Declaration of Helsinki.

### Procedures

### Hop Tests

Hop tests were conducted as previously described. Participants performed 3 practice trials for each single-leg hop test condition in the following order: single hop for distance (SLH), triple hop for distance (TH), crossover hop for distance (CH), and 6-m hop for time (6H). After the practice trials, starting with the preferred leg and switching legs after each trial to minimize fatigue, 3 trials for each condition were tested in the same order, with 30-second rest between trials. The trial was considered valid if the participant was able to hold the landing position for 2 seconds. Hops were considered invalid and were repeated if the participant touched the contralateral foot on the ground, lost balance, or made additional hops after landing. Participants' arms were unconstrained during the hop. Side to side difference above 10% was considered asymmetry for hop tests **(10)**.

### 10 yards Lower Extremity Functional Test (LEFT)

Functional movements of lower extremities were measured with 10-yd LEFT. Two lines were marked as A and B lines 10 yards apart (Figure 1). The test consisted of 7 consecutive conditions which need to be performed without interruption between these lines. Participants take the starting position at line A while facing line B. With the "go" command, participants sprint forward then backpedal to line A, then side shuffle to line B and side shuffle back to line A. Next, they carioca to line B and carioca back to line A. Finally, they sprint and pass line B. The participants were required to make sure to touch or pass each line with their foot to complete a valid test. Two administrators measured the time. Players were divided into low performer and high performer groups, according to median value for LEFT test complete time.

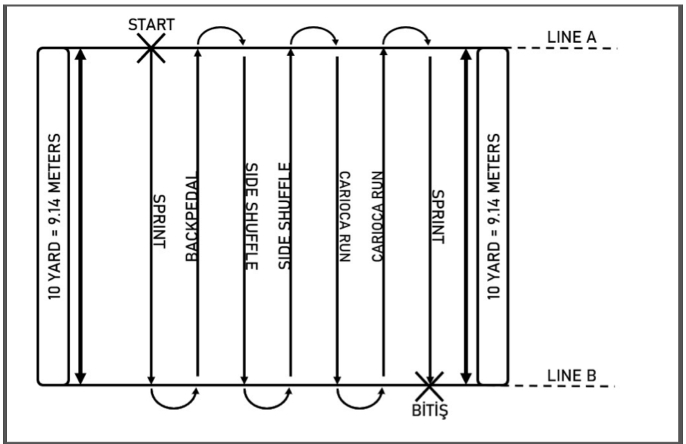


**Figure 1.** Lower Extremity Functional Test

### Statistical Analysis

The frequencies and percentages are given for categorical variables as descriptive statistics. To determine an adequate sample size in order to achieve statistical significance with a = 0.05, 80% power and effect size (f) = 0.2526 (calculated based on a partial ŋ2 = 0.06), a priori power analysis was performed using an online power analysis application (G*Power 3.1.9.2. Franz Faul, Universität Kiel, Germany). The results of the power analysis indicated a total sample size of at least 23 subjects. The associations between two categorical variables were analysed with Pearson's chi-squared test or the Fisher's exact test (if not possible to compute the test, simulated p-value was used). Independent samples t-test and analysis of variance (ANOVA) were used to analyse the differences between/among means of a numerical variable. Pearson correlation was used investigate linear relationship between numerical variables. Statistical significance was assessed at $p<0.05$ and all statistical analyses were performed using R software (R software, version 4.0.5, package: arsenal, R Foundation for Statistical Computing, Vienna, Austria; http://r.project.org).

## RESULTS

Body compositions and test performances based on playing position groups are presented in Table 1. Significant differences between groups were observed for hop tests (SLH, TH, CH) and LEFT (Table 2).

**Table 1.** Body compositions and test performances by playing position groups

| | SP (N=8) | | BSP (N=9) | | LM (N=9) | | |
|---|---|---|---|---|---|---|---|
| | Mean (SD) | Range | Mean (SD) | Range | Mean (SD) | Range | p value |

**Table 1.** Body compositions and test performances by playing position groups

| | SP (N=8) | | BSP (N=9) | | LM (N=9) | | |
|---|---|---|---|---|---|---|---|
| | Mean (SD) | Range | Mean (SD) | Range | Mean (SD) | Range | p value |
| **BMI (kg/m²)** | 23.55 (2.14) | 20.90 - 27.00 | 25.61 (3.36) | 19.40 - 29.80 | 32.16 (3.62) | 28.00 - 39.50 | < 0.001* |
| **BF%** | 11.82 (4.63) | 5.10 - 15.80 | 11.51 (4.53) | 4.10 - 17.00 | 21.38 (6.07) | 12.30 - 28.50 | < 0.001* |
| **SLH-Left (m)** | 1.10 (0.11) | 0.89 - 1.21 | 1.11 (0.17) | 0.84 - 1.40 | 0.95 (0.11) | 0.78 - 1.11 | 0.025* |
| **SLH-Right (m)** | 1.12 (0.11) | 0.90 - 1.23 | 1.12 (0.14) | 0.83 - 1.27 | 0.95 (0.11) | 0.79 - 1.11 | 0.007* |
| **SLH-Ratio (%)** | 0.99 (0.11) | 0.84 - 1.14 | 0.99 (0.08) | 0.91 - 1.14 | 1.01 (0.11) | 0.86 - 1.24 | 0.962 |
| **TH-Left (m)** | 3.57 (0.43) | 2.81 - 4.10 | 3.21 (0.38) | 2.32 - 3.57 | 3.08 (0.37) | 2.60 - 3.68 | 0.046 |
| **TH-Right (m)** | 3.62 (0.35) | 3.16 - 4.13 | 3.24 (0.31) | 2.51 - 3.49 | 2.89 (0.30) | 2.55 - 3.51 | < 0.001* |
| **TH-Ratio (%)** | 0.98 (0.05) | 0.89 - 1.05 | 0.99 (0.04) | 0.92 - 1.05 | 1.07 (0.12) | 0.95 - 1.38 | 0.066 |
| **CH-Left (m)** | 3.34 (0.40) | 2.81 - 3.94 | 2.89 (0.34) | 2.09 - 3.31 | 2.53 (0.27) | 2.19 - 3.07 | < 0.001* |
| **CH-Right (m)** | 3.31 (0.51) | 2.44 - 4.02 | 3.00 (0.35) | 2.21 - 3.32 | 2.64 (0.36) | 2.20 - 3.39 | 0.010* |
| **CH-Ratio (%)** | 1.02 (0.11) | 0.94 - 1.29 | 0.96 (0.04) | 0.92 - 1.04 | 0.97 (0.11) | 0.83 - 1.17 | 0.381 |
| **6H-Left (sec)** | 1.73 (0.47) | 1.27 - 2.82 | 1.77 (0.21) | 1.48 - 2.12 | 2.00 (0.13) | 1.83 - 2.27 | 0.143 |
| **6H-Right (sec)** | 1.77 (0.44) | 1.21 - 2.61 | 1.72 (0.22) | 1.44 - 2.02 | 1.96 (0.25) | 1.44 - 2.31 | 0.265 |
| **6H-Ratio (%)** | 0.98 (0.09) | 0.80 - 1.08 | 1.03 (0.05) | 0.95 - 1.13 | 1.04 (0.14) | 0.85 - 1.27 | 0.369 |
| **10YDLEFT (sec)** | 20.48 (2.15) | 18.08 - 24.43 | 22.01 (2.47) | 19.21 - 25.93 | 23.67 (2.48) | 20.09 - 27.03 | 0.037* |

Linear Model ANOVA was used for analysis.

*. The mean difference is significant at the 0.05 level.

6H=6-m hop for time. 10YDLEFT= 10 yards lower extremity functional test. BF%= Body fat ratio. BMI= Body Mass Index. BSP= Big Skill Players. CH= crossover hop for distance. LM=Linemen. SLH= single hop for distance. SP= Skill Players. TH= triple hop for distance.

For the hop tests on the left leg, the performance of the SP group was superior to LM for TH (p=0.049), and CH (p<0.001). The performance of BSP was inferior to SP for CH (p=0.034), and was superior to LM for SLH (p=0.043). For the hop tests on the right leg, the performance of SP was superior to LM for SLH (p=0.024), TH (p<0.001) and CH (p=0.008), and the performance of BSP was superior to LM for SLH (p=0.015). In LEFT, the SP group was significantly faster than LM (p = 0.034). The performance on the remaining tests and conditions were not significantly different between the groups based on playing positions.

**Table 2.** Post-hoc analysis for comparisons between two groups

| | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| **SLH-Left** | SP | BSP | -0.01 | 0.07 | 1.000 | -0.18 | 0.16 |
| | SP | LM | 0.16 | 0.07 | 0.070 | -0.01 | 0.33 |
| | BSP | LM | 0.17* | 0.06 | 0.043* | 0.00 | 0.33 |
| **SLH-Right** | SP | BSP | -0.01 | 0.06 | 1.000 | -0.16 | 0.15 |
| | SP | LM | 0.17* | 0.06 | 0.024* | 0.02 | 0.32 |
| | BSP | LM | 0.18* | 0.06 | 0.015* | 0.03 | 0.32 |
| **TH-Left** | SP | BSP | 0.36 | 0.19 | 0.215 | -0.13 | 0.84 |
| | SP | LM | 0.49* | 0.19 | 0.050* | 0.00 | 0.97 |
| | BSP | LM | 0.13 | 0.18 | 1.000 | -0.34 | 0.60 |
| **TH-Right** | SP | BSP | 0.38 | 0.15 | 0.062 | -0.02 | 0.78 |
| | SP | LM | 0.73* | 0.15 | <0.001* | 0.34 | 1.13 |
| | BSP | LM | 0.35 | 0.15 | 0.079 | -0.03 | 0.74 |
| **CH-Left** | SP | BSP | 0.45* | 0.16 | 0.034 | 0.03 | 0.87 |
| | SP | LM | 0.81* | 0.16 | <0.001* | 0.39 | 1.23 |
| | BSP | LM | 0.36 | 0.16 | 0.100 | -0.05 | 0.77 |
| **CH-Right** | SP | BSP | 0.30 | 0.20 | 0.417 | -0.21 | 0.82 |
| | SP | LM | 0.67* | 0.20 | 0.008* | 0.15 | 1.18 |
| | BSP | LM | 0.36 | 0.19 | 0.223 | -0.14 | 0.86 |
| **10YDLEFT** | SP | BSP | -1.53 | 1.19 | 0.637 | -4.61 | 1.55 |
| | SP | LM | -3.19* | 1.16 | 0.034* | -6.19 | -0.20 |
| | BSP | LM | -1.67 | 1.16 | 0.490 | -4.66 | 1.33 |

Multiple Comparisons Bonferroni was used for analysis.

*. The mean difference is significant at the 0.05 level.

6H=6-m hop for time. 10YDLEFT= 10 yards lower extremity functional test. BSP= Big Skill Players. CH= crossover hop for distance. LM=Linemen. SLH= single hop for distance. SP= Skill Players. TH= triple hop for distance.

Among the 26 players, 8 players had SLH asymmetries (30.8%), 3 players had TH asymmetries (11.5%), 5 players had CH asymmetries (19.2%), and 6 players had 6H asymmetries (23.1%) (Table 3). High performer group had significantly better performances than low performance group for TH, CH and 6H tests (p<0.05) (Table 4).

**Table 3.** Asymmetries by playing position groups

| | SP (N=8) | | BSP (N=9) | | LM (N=9) | | |
|---|---|---|---|---|---|---|---|
| | < %10 | ≥ %10 | < %10 | ≥ %10 | < %10 | ≥ %10 | p value |
| **SLH** | 5 (62.5%) | 3 (37.5%) | 7 (77.8%) | 2 (22.2%) | 6 (66.7%) | 3 (33.3%) | 0.874 |
| **TH** | 7 (87.5%) | 1 (12.5%) | 9 (100.0%) | 0 (0.0%) | 7 (77.8%) | 2 (22.2%) | 0.502 |
| **CH** | 7 (87.5%) | 1 (12.5%) | 9 (100.0%) | 0 (0.0%) | 5 (55.6%) | 4 (44.4%) | 0.054 |
| **6H** | 7 (87.5%) | 1 (12.5%) | 8 (88.9%) | 1 (11.1%) | 5 (55.6%) | 4 (44.4%) | 0.291 |
| | **High performers (< 21.67 seconds)** | **Low performers (≥ 21.67 seconds)** | **High performers (< 21.67 seconds)** | **Low performers (≥ 21.67 seconds)** | **High performers (< 21.67 seconds)** | **Low performers (≥ 21.67 seconds)** | |
| **10YDLEFT** | 6 (75.0%) | 2 (25.0%) | 4 (50.0%) | 4 (50.0%) | 3 (33.3%) | 6 (66.7%) | 0.286 |

Fisher's Exact Test for Count Data was used for analysis.

6H=6-m hop for time. 10YDLEFT= 10 yards lower extremity functional test. BSP= Big Skill Players. CH= crossover hop for distance. LM=Linemen. SLH= single hop for distance. SP= Skill Players. TH= triple hop for distance.

**Table 4.** Comparison of Hop Test scores according to 10YDLEFT scores

| | High performers (10YDLEFT < 21.67 sec ) (n=13) | Low performers (10YDEFT ≥ 21.67 sec) (n=12) | p value |
|---|---|---|---|
| **SLH-Left (m)** | 1.07 (0.11) | 1.03 (0.19) | 0.558 |
| **SLH-Right (m)** | 1.08 (0.14) | 1.02 (0.15) | 0.285 |
| **SLH-Ratio (%)** | 0.99 (0.08) | 1.01 (0.11) | 0.645 |
| **TH-Left (m)** | 3.47 (0.38) | 3.06 (0.40) | 0.015* |
| **TH-Right (m)** | 3.45 (0.39) | 2.98 (0.34) | 0.004* |
| **TH-Ratio (%)** | 1.01 (0.05) | 1.03 (0.12) | 0.509 |
| **CH-Left (m)** | 3.15 (0.41) | 2.63 (0.39) | 0.003* |
| **CH-Right (m)** | 3.16 (0.52) | 2.76 (0.37) | 0.039* |
| **CH-Ratio (%)** | 1.01 (0.11) | 0.95 (0.07) | 0.149 |
| **6H-Left (sec)** | 1.69 (0.18) | 2.01 (0.35) | 0.009* |
| **6H-Right (sec)** | 1.70 (0.29) | 1.96 (0.31) | 0.039* |
| **6H-Ratio (%)** | 1.01 (0.11) | 1.03 (0.10) | 0.690 |

Independent sample t-test was used for analysis.

6H=6-m hop for time. 10YDLEFT= 10 yards lower extremity functional test. CH= crossover hop for distance. SLH= single hop for distance. TH= triple hop for distance.

### Correlations

Correlations are presented in Figure 2. BF% was significantly negatively correlated with SLH and CH, and positively correlated with 6H for both legs. BMI was significantly negatively correlated with SLH and CH, and positively correlated with 6H and TH-ratio for both legs. LEFT was significantly negatively correlated with TH and CH, and positively correlated with 6H for both legs. For hop tests, 6H was significantly negatively correlated with SLH, TH and CH tests for both legs. SLH, TH and CH were significantly positively correlated with each other. LEFT was not correlated with BMI or BF%.

## DISCUSSION

The main findings of the study were; **i)** BMI and BF% had correlations with LEFT performances, **ii)** LEFT and hop test performances differed between playing positions, **iii)** LEFT performance was related with the performance in hop tests, and iv) side-to-side asymmetries were not related with any of the test performances.

Consistent with previous studies (17,18), the LM group performed significantly worse than other positions in speed and agility tests. Since there is a positive correlation between body mass and time to complete shuttle test (19)and the LM group has higher body mass among the groups, the lower performance may be expected during the LEFT test. However, results showing that there were no significant differences between the BMI values of drafted and undrafted NFL players support that BMI alone may not be sufficient to predict performance (20). American football players mostly have higher BMI than the recommended normal value for healthy adults of 25 kg/m² (21,22). Due to the game characteristics of American football, the higher momentum caused by their high body masses may be desirable for players as it provides some performance advantages over their opponents, especially in contact moves such as tackles and blocks. Considering these game characteristics and the previous findings showing the high prevalence overweight and obesity, we performed different statistical analyses with two cut-off values for BMI to evaluate the relationship between body mass and test performances. When the analyses are performed for BMI with the cut-off value set to 25 kg/m², there was a significant difference between the groups only for the CH test, while significant differences were observed in the SLH and CH for hop tests, and also for LEFT when this limit was set to 30 kg/m². In the study by Brumitt et al., BMI was associated with increased risk of injuries in the lower extremity, but not the jump measures (23). Unlike our study group, they investigated athletes with normal BMI (<25 kg/m²). Thus, the stability of their athletes may not have been challenged in hop tests. However, higher BMI values in our study group might have affected stability during sport-specific movements such as cutting and momentum changing; thereby, affecting athletic performance. Therefore, considering that the combination of different athletic skills impacts overall athletic performance, AmF players should not only focus on increasing their BMI to increase their strength, they should also consider the effects of having higher BMI on speed and agility. We suggest that BMI values different than conventional cut-off values may be considered when evaluating the performances and injury risks of AmF players, especially for playing positions requiring more prominent speed and agility skills.

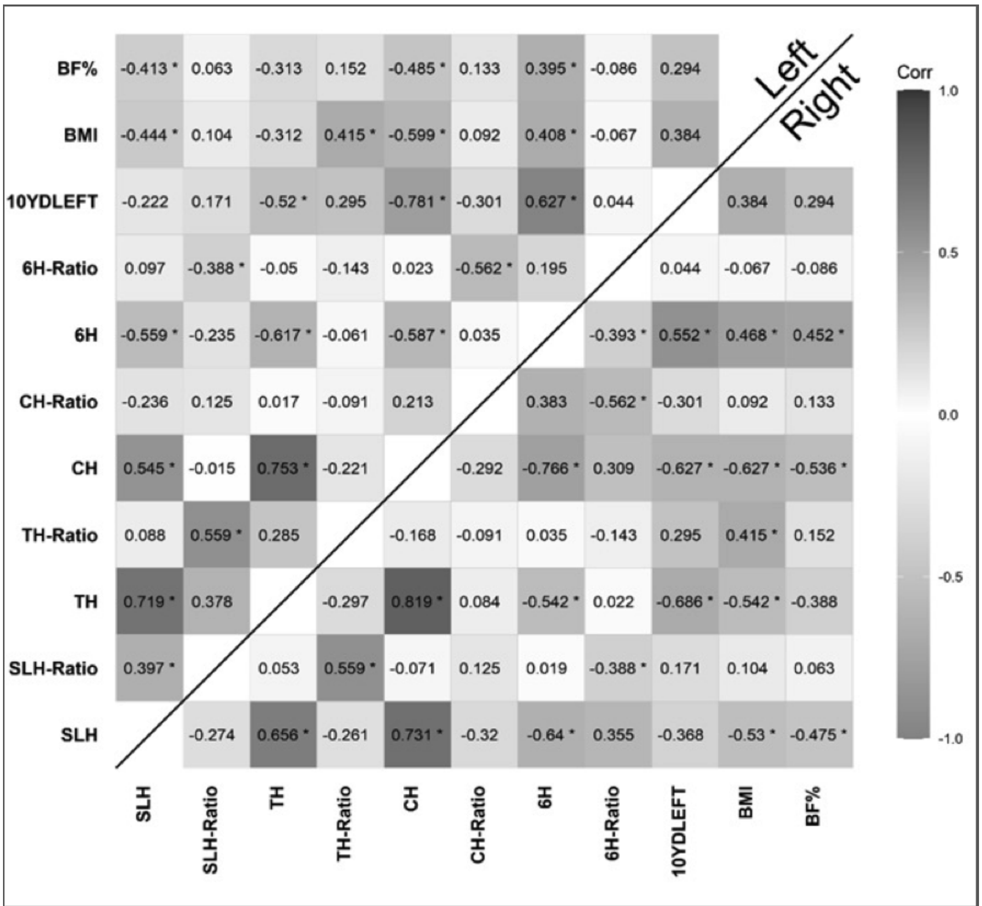


**Figure 2.** Correlations

Evaluating obesity or health status in AmF players only with BMI would likely to lead false positive results and hence body fat percentage will be a more accurate measure (20,22,24). Additionally, the findings showing that the drafted players had lower body fat percentage in most playing positions compared to undrafted players suggest that body fat percentage not only indicates health status, but should also be taken into consideration when performance is evaluated. Our findings suggest that both BMI and BF% were significantly negatively correlated with hop test results but not significantly correlated with LEFT. Therefore body composition measures may affect specific performance test measures like hop tests but not functional performance tests. Functional performance should be investigated with a multifactorial approach.

Hop tests are instruments with well-known benefits such as evaluating the rehabilitation process after sports injuries or determining when to return to sports (25–27). Also, they were shown to be useful when evaluating sports skills such as power in healthy athletes (27). Considering the game characteristics of AmF, which involves fast and powerful single limb movements, we investigated whether hop tests were useful in evaluating more complex sport-specific performance. Our results showed that 10 yard LEFT time was positively correlated with 6H time and negatively correlated with CH and TH test scores. These results suggest that hop tests may also be useful when evaluating speed, agility and power performance of healthy athletes.

Contrary to our hypothesis, balance and hop test asymmetries were not different between playing positions and there were no significant correlations between asymmetries and performance tests. Previous studies presented similar findings showing that the speed and agility performance, which were evaluated with change of direction tests, were not impaired by hopping (28) or jumping asymmetries (29). This may be linked to the notion suggesting the task specificity of asymmetries in sports performance (12). Differences in application may lead to task specificity of asymmetries. For example, an asymmetry in controlling sagittal plane forces may be expected to affect hop tests more than agility tests. Moreover, leg preference may differ when executing motor tasks, meaning that skill dominant and force dominant legs may not be the same (12). The study by van Melick et al. about how to determine leg dominance showed that 66.7% of the participants preferred the same leg for kicking and standing tasks, which supports our suggestions about leg preference differences between tasks (30). Additionally, considering the previous literature showing that limb asymmetry can be affected by an athlete's general training status and task familiarity (12,31), the effects of single leg asymmetries may not have been observed, as the distance, movement patterns and functionality in LEFT are similar to both AmF game and training, and AmF players may have found LEFT more familiar compared to single leg tests. Therefore, healthcare providers and athletic trainers may consider asymmetries in a task specific manner when evaluating athletes.

There are several limitations of this study. First, we investigated a specific group which consisted of AmF players; therefore, these results cannot be generalized to different athletic populations. Secondly, the small number of participants can be considered as a limiting factor; however, the number of participants in our study was comparable with studies which have similar designs. For example, the number of participants in our study was equal to the study by Tatlıcıoğlu et al. which evaluated lower limb asymmetries in strength tests of Turkish collegiate AmF players (32), and was higher than two studies investigating the impact of hop performance on leg muscle power (27) or change of direction speed (28). However, increasing the number of participants for all playing positions in future studies will allow the evaluation of the effects of physical characteristics such as BMI and body fat ratio on performance for players with different in-game skill and movement patterns. Another limitation is the method we used for measuring body fat ratio. We used the bioimpedance method to measure body composition. It is known that the predictive accuracy of BIA is less than other laboratory methods for estimating body fat ratio. However, we used BIA for feasibility and accessibility purposes. Despite the limitations, the highlights of our study warrants further investigations with larger groups, different sports or using these tests to evaluate the efficiency of training programs.

## CONCLUSION

Physical characteristics and playing positions were shown to correlate with performance tests. Future studies involving larger samples for all playing positions and also from different athletic populations would provide valuable contributions to current knowledge by evaluating the effects of physical characteristics such as BMI and body fat ratio, and also hop test performance, for players with different in-game skill and movement patterns.

***Ethics Committee Approval / Etik Komite Onayı***

The approval for this study was obtained from Ege University, Clinical Research Ethics Committee, Izmir, Türkiye (Decision no: 21-5T/64 Date: 06.05.2021).

***Conflict of Interest / Çıkar Çatışması***

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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***Author Contributions / Yazar Katkıları***

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