Relationship between CHU-Test Results and High-intensity Running during Soccer Matches

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The purpose of this study was to investigate relationship between the results of CHU-Test (a Test to Carry out High-intensity running with Utmost turns, repeatedly) and high-intensity running (HIR) during soccer matches. Twenty-four male soccer players (university students) aged 19.3±0.9 years were participated in the study. To assess intermittent endurance in soccer, participants performed the CHU-Test and soccer matches. They put on global positioning system (GPS) devise in soccer matches to measure total distance covered (TD), distance covered more than 18.0 km/h (HIR), ratio of HIR to TD (HIR/TD) and distance covered more than 24.0 km/h (Sprinting). CHU-Test results of participants were 17.9±2.6 times in first time and 18.0±3.1 times in second time. Between their results, there was a significant reliability coefficient of 0.95 ($p < 0.05$). Additionally, significant correlation coefficients ($r = 0.67$ to 0.76) were showed between the CHU-Test results and HIR, HIR/TD and Sprinting at full time (90-minute), peak 5-minute period and final 15-minute period (75 to 90 minute) of soccer matches ($p < 0.05$). From these results, it was suggested that the CHU-Test was a field test that was relevant to HIR during soccer matches.

Keywords: GPS, intermittent endurance, running performance, physical fitness

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1. Introduction

Soccer is a sport in which two opposing teams compete for points during a 90-minute match. Therefore, the purpose of the match is to score points and prevent the loss of potential points. In decisive situations associated with scoring (Faude et al., 2012) or effective attacks that lead to decisive situations (Kai et al., 2018; Tenga et al., 2010), high-intensity running (HIR), including sprinting, is often used. In addition, according to Mohr et al. (2003), the higher the competitive level is in professional soccer matches, the more often HIR is performed. This shows the importance of intermittent endurance for repeated HIR. Furthermore, in soccer matches played in the English premier league and the Spanish la liga, HIR has been performed with increasing frequency (Bush et al., 2015; Pons et al., 2021), suggesting an increase in the importance of intermittent endurance.

Recent progress in science and technology makes it possible to acquire big data from running performances using the global positioning system (GPS) and tracking systems. However, it is a challenge to use the GPS and tracking systems for youth soccer training due to physical (ensuring devices and stadiums that are capable of measurement) and human resource (ensuring measurers and analyzers) issues. Therefore, it is necessary to conduct field tests associated with HIR during soccer matches to gain a simple understanding of intermittent endurance.

The CHU-Test (a Test to Carry out High-intensity running with Utmost turns, repeatedly) is a simple field test designed to measure intermittent endurance of soccer players (CHU-Test, 2021a). In this test, players run back and forth twice in the 16.5-meter penalty area of the soccer pitch, and repeat two laps, with a 10-second break in between, until they are exhausted in response to a beep, which accelerates speed gradually. The CHU-Test has certain advantages compared with existing field tests used to assess intermittent endurance. The biggest advantage is that

the CHU-Test can measure intermittent endurance on a soccer pitch, which clearly shows the penalty area, using the beep alone. In addition, the beep used in the CHU-Test is the 3-count beep used when changing directions and making goals, and the 3-count beep makes it easy to adjust the running speed, and makes it easy for instructors or judges to estimate the timing of the beep when players make goals. As explained above, the CHU-Test is a convenient field test for use when teaching soccer.

However, there are no reports clarifying the relationship between CHU-Test results and HIR during soccer matches. Clarifying the relationship is necessary for use of the CHU-Test as a field test associated with HIR performed during soccer matches.

Thus, this study was conducted to investigate the relationship between the CHU-Test results and HIR during soccer matches.

2. Methods

2.1. Participants

Participants of this study were 24 male soccer players (age: 19.3±0.9 years old, height: 173.5±5.1 cm, weight: 64.5±4.8 kg) belonging to university soccer clubs participating in the Tokai university students football league 1 (U1-league). Participants were all Japanese and goal keepers were excluded. This study was conducted as a part of training under the supervision of university instructors. All data obtained through this study were used for secondary purposes after obtaining consent from all participants. This study was approved by the Chubu University Ethics Review Committee (Approval number: 20210036).

2.2. Procedures

Procedures of this study are shown in **Table 1**. After a preliminary test to become accustomed to the CHU-Test, participants repeated the CHU-Test twice with a one-week interval according to the test-retest method. We scheduled dates for the CHU-Test on the day following a rest day and at least 48 hours after a soccer match. In order to understand the running performance of participants during soccer matches, participants wore GPS devices and played in soccer matches. We used GPS data of participants who played full time in soccer matches for analyses. In order to ensure a sufficient number of participants, we used data from five soccer matches (three U1-league matches, one Tokai independence league match, and one training match (TRM)) performed within eight days before and after the retest day, whose data were used as CHU-Test results. On the first Saturday, the participants played either one U1-league match or one TRM. Obtained GPS data from individual participants were used to calculate mean values, and we examined the relationship between the mean values and CHU-Test results. In order to ensure sufficient data, we also used data from the participants whose GPS data was obtained from one game only.

2.3. CHU-Test

In the CHU-Test (CHU-Test, 2021a) players run back and forth twice in the penalty area (16.5 meter) of the soccer pitch repeatedly with a 10-second break

Table 1 Experimental procedure

Week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 0	Recovery	Off	**Pretest**	Training	Training	Training	U1-league or TRM
Week 1	Recovery	Off	**Test**	Training	Training	Training	**U1-league (GPS)** or **TRM (GPS)**
Week 2	Recovery	Off	**Retest**	Training	Training	Training	**U1-league (GPS)**
Week 3	Off or **I-league (GPS)**	Recovery or Off	Training	**U1-league (GPS)**	Recovery or Training	Off	Off

U1-league: Tokai university students football league 1, **I-league**: Tokai independence league, **TRM**: Training match

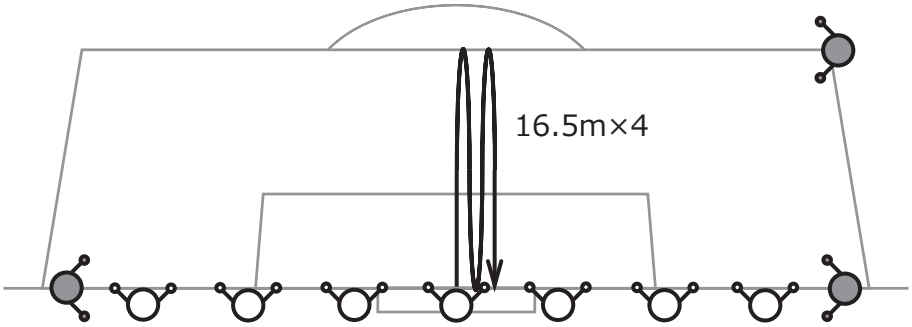

Figure 1 The CHU-Test

in between until they are exhausted in response to a beep, which accelerates speed gradually (**Figure 1**). Specifically, participants stand still at the goal line, and start running in response to the beep in accordance with the CHU-Test explanatory video (CHU-Test, 2021b). Next, participants run back and forth a distance of 16.5-meter twice in response to the 3-count beep directing the participant to change direction. And then, participants reach or pass the goal line before the 3-count beep ends. After a 10-second break, participants repeat the process. From the second start, the three-count beep is replaced be a single beep. Participants must be ready at the goal line before the second beep and start running when the beep sounds. Warnings are issued once for inadvertent false starts, and measurement is ended if there is a second false start. If the participant makes a false start intentionally, the measurement is immediately ended. Participants repeat two-lap runs until they are exhausted, and the number of runs, including those in which the 3-count beep sounds before the player reaches the goal. The number of repetitions at each speed level in the CHU-Test is shown in **Table 2**. Before the test, participants warm up sufficiently.

2.4. Running Performance during Soccer Matches

In order to understand the running performance of participants during soccer matches, we measured total distance covered (TD) during each match (90 minutes), and distance covered by speed range using the GPS device (SPI High Performance Unit manufactured by GPSports). Speed range was classified into 6km/h increments (0-6km/h, 6-12km/h, 12-18km/h, 18-24km/h, 24-30km/h, 30km/h or more). Distance covered at greater than 18km/h was defined as high-intensity running (HIR), and distance covered at greater than 24km/h was defined as Sprinting (Hill-Haas et al., 2009; Kai et al., 2018). In regard to HIR during soccer matches, we also calculated the ratio of HIR to TD (HIR/TD, which is considered the quality of running). In regard to TD, HIR, HIR/TD, and Sprinting, we calculated both the values for the 90-minute period (full time) and the values every 5 and 15 minutes, and used the TD, HIR, HIR/TD, and Sprinting in the peak 5-minute period, which means the period with the highest intensity, and the final 15-minute period which means the period with the highest scores during a soccer match (Bangsbo et al., 2008: Mohr et al., 2010). We targeted participants who performed full time for analyses, and obtained data from 1.8±0.9 soccer matches (three matches maximally) from 16 participants respectively.

Table 2 CHU-Test protocol

(Unit: times)

Speed level	Number of repetitions				
	1	2	3	4	5
Level 1	1				
Level 2	2	3			
Level 3	4	5	6		
Level 4	7	8	9	10	
Level 5	11	12	13	14	15
Level 6	16	17	18	19	20
Level 7	21	22	23	24	25
Level 8	26	27	28	29	30
Level 9	31	32	33	34	35
Level 10	36	37	38	39	40

2.5. Statistical Analyses

All measurement results are shown in mean value ± standard deviation. In order to examine the reliability of the CHU-Test, we used the test-retest method. We performed t-test to compare the first and second CHU-Test results. We also conducted Pearson's correlation analysis to examine the relationship between CHU-Test results and HIR, HIR/TD, and Sprinting during soccer matches. SPSS 12.0J for Windows was used for all statistical analyses. Statistical significance was set at 0.05 (α=0.05).

3. Results

3.1. Reliability Measured by Test-retest Method

CHU-Test results were 17.9±2.6 times (minimum value was 13 times and maximum value was 23 times) for the first time and 18.0±3.1 times (minimum value was 13 and maximum value was 25 times) for the second time. According to the t-test, there was no significant difference between their results ($p < 0.05$). Additionally, we obtained a significant reliability coefficient of 0.95 ($p < 0.05$) between the results of the CHU-Test (**Figure 2**).

3.2. Running Performance during Soccer Matches

Table 3 shows the running performance of participants during soccer matches. TD, HIR, HIR/TD, and Sprinting for full time during soccer matches revealed 11357±631m, 1139±281m, 10.0±2.3%, and 175±105m, respectively. TD, HIR, HIR/TD, and Sprinting for the peak 5-minute period during soccer matches were 727±41m, 119±25m, 16.4±3.2%, and 39±15m, respectively. TD, HIR, HIR/TD, and Sprinting for the final 15-minute period during soccer matches revealed 1698±114m, 167±46m, 9.8±2.4%, and 29±26m, respectively.

3.3. Relationships between CHU-Test Results and HIR, HIR/TD, and Sprinting during Soccer Matches

We examined the relationships between CHU-Test results of the participants of this study with HIR, HIR/TD, and Sprinting during soccer matches. As a result, correlation coefficients between CHU-Test results and HIR, HIR/TD, and Sprinting for full time during soccer matches were $r = 0.72$, $r = 0.71$, $r = 0.73$, respectively (**Figure 3**), those for peak 5-minute period during soccer matches were $r = 0.68$, $r = 0.67$, $r = 0.70$ respectively (**Figure 4**), and those for the final 15-minute period during soccer matches were $r = 0.76$, $r = 0.73$, $r = 0.71$, respectively (**Figure 5**). All showed significant values ($p < 0.05$).

4. Discussion

The purpose of this study was to examine the relationship between CHU-Test results and HIR

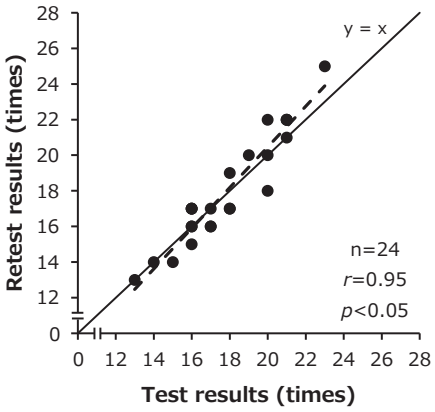

Figure 2 Test-retest reliability of CHU-Test

Table 3 Running performance during soccer matches (n=16)

Item	TD (m)	HIR (m)	HIR/TD (%)	Sprinting (m)
Full time (90 minutes)	11357 ± 631	1139 ± 281	10.0 ± 2.3	175 ± 105
Peak 5-minute period	727 ± 41	119 ± 25	16.4 ± 3.2	39 ± 15
Final 15-minute period	1698 ± 114	167 ± 46	9.8 ± 2.4	29 ± 26

TD: Total distance covered, HIR: High-intensity running

during soccer matches. As a result, significant correlation coefficients (r = 0.67 to 0.76) were observed between the CHU-Test results and HIR, HIR/TD and Sprinting during soccer matches.

First, we employed the test-retest method to examine the reliability of CHU-Test. The results showed a significant reliability coefficient between the first and second CHU-Test results (r = 0.95) (**Figure 2**). Additionally, no significant difference was observed between the first and second CHU-Test results ($p \geqq 0.05$). These results suggested that CHU-Test was a highly reliable test.

Next, we analyzed the relationship between the CHU-Test results and HIR for full time. Results showed a significant correlation between the two (**Figure 3**). Krustrup et al. (2003) examined the relationship between the results of Yo-Yo IR1 test, an intermittent endurance indicator similar to the CHU-Test, and distance covered under HIR (15km/h or more) by players during soccer matches. They confirmed a significant correlation between the two (r = 0.71). In addition, Randers et al. (2009) examined the relationship between Yo-Yo IR2 test results and distance covered under HIR (15km/h or more) of professional soccer players in Denmark during soccer matches. They confirmed a significant correlation between the two (r = 0.747). Although the HIR in this study was defined as 18.0km/h or more, this study also revealed a significant correlation between the two as the above-mentioned previous study did. The correlation coefficient (r = 0.72) was also similar to that of the previous study. In addition, this study confirmed that CHU-Test results were significantly correlated to HIR/TD in full time, which shows the quality of running, and to Sprinting in full time, which shows the amount of running in a higher speed range of HIR (**Figure 3**). These suggested that CHU-Test results correlate with HIR during soccer matches.

The intensity of play during a 90-minute soccer match varies significantly, with high-intensity movement occurring intermittently (Mohr et al., 2003). Mohr et al. (2003) classified 90-minute matches into 5-minute intervals to calculate distance covered under HIR (15km/h or more) and compared these mean values with distance covered under HIR during the peak 5-minute period. As a result, distance covered under HIR during the peak 5-minute period by top-class player were 81% higher than the mean values, and those by moderate player were 64% higher than the mean values. Distance covered under HIR during the peak 5-minute period by top-class players was significantly higher (27%) than that exhibited by moderate players. These suggested that the higher the level of competition becomes, the more HIR is required during the peak 5-minute period.

This study confirmed a significant correlation between the CHU-Test results and HIR during the peak 5-minute period (**Figure 4**). A study on the relationship between the results of Yo-Yo IR2 test conducted on professional soccer players and distance covered under HIR (15km/h or more) during soccer matches by Bangsbo et al. (2008) showed a significant correlation (r = 0.72). Because previous studies have not reported the relationship between the Yo-Yo IR2 test results and distance covered by HIR (18km/h or more), it is inappropriate to simply compare these with the results of our study. However, the correlation coefficient (r = 0.68) obtained from our study showed a similar value with the above-mentioned previous studies. In addition, the significant correlation observed between the CHU-Test results and HIR/TD, and Sprinting during the peak 5-minute period in this study (**Figure 4**) suggested that the CHU-Test results are correlated with the HIR during the peak 5-minute period.

In the Japan Professional Football League (J-League), the calculation of scores of every 15 minutes in soccer matches from 2003 to 2020, when the J-League decided not to extend matches, revealed a greater incidence of scoring in the final 15-minute period (75-90 minute) for both the J1-League and J2-League (J-League, 2021). Mohr et al. (2003) reported that the distance covered by the HIR of professional players during soccer matches tended to decrease toward the end of matches, and showed the lowest value in the final 15-minute period. However, the distance covered by the HIR of the top-class players showed significantly higher values than were seen for the moderate players. Therefore, it is suggested that the higher the soccer competition level becomes, the more HIR is required in the final 15-minute period resulting in the highest scores in soccer matches.

Analysis of the relationship between the CHU-Test results and HIR during the final 15-minute period revealed a significant correlation between the two (**Figure 5**). Mohr et al. (2010) examined the Yo-Yo IR1 test results and distance covered by the HIR (13km/h or more) of the professional soccer players in the second and third leagues in Spain, and confirmed a significant correlation between the them

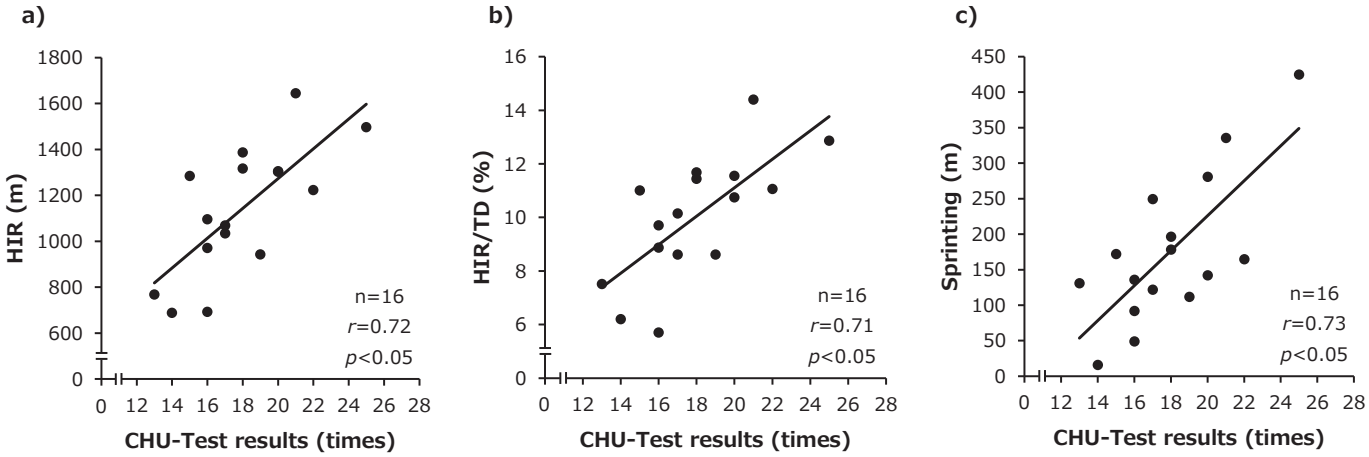

Figure 3 Relationships between CHU-Test results and **a)** HIR, **b)** HIR/TD, and **c)** Sprinting during soccer matches (Full time)

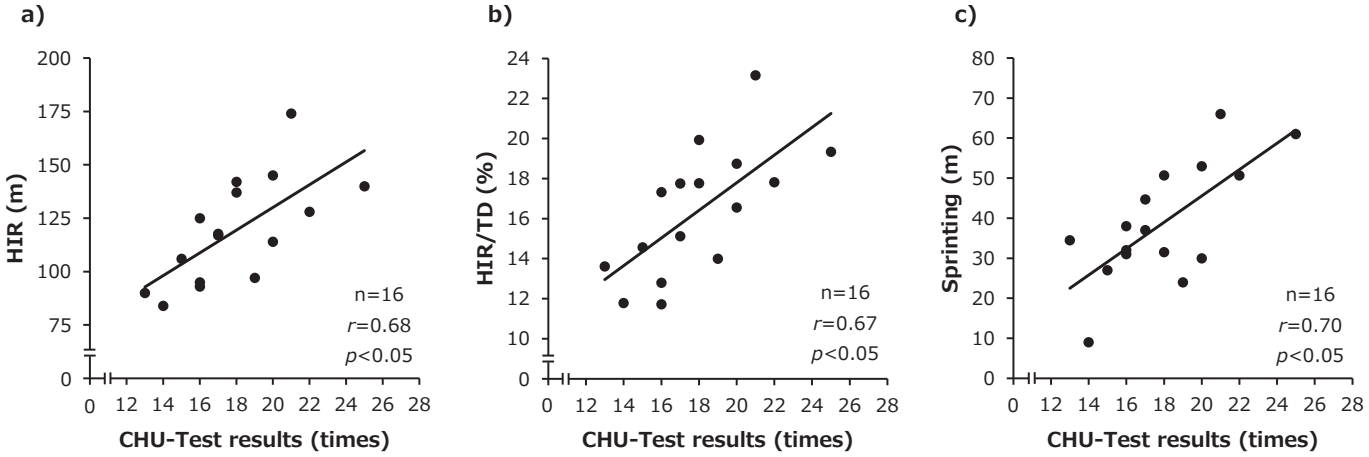

Figure 4 Relationships between CHU-Test results and **a)** HIR, **b)** HIR/TD, and **c)** Sprinting during the peak 5-minute period of soccer matches

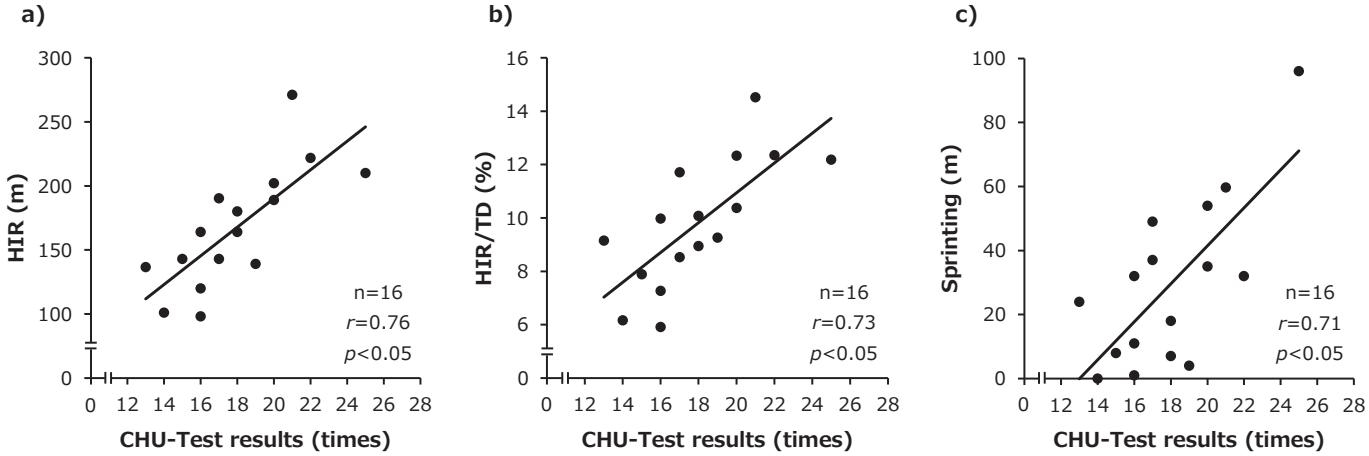

Figure 5 Relationships between CHU-Test results and **a)** HIR, **b)** HIR/TD, and **c)** Sprinting during the final 15-minute period of soccer matches

(r = 0.51). Because previous studies have not reported the relationship between the Yo-Yo IR1 test results and distance covered by HIR (18km/h or more), it is inappropriate to simply compare these with the results of our study. However, the correlation coefficient (r = 0.76) obtained from our study showed a higher

value from the above-mentioned previous studies. In addition, the significant correlation observed between the CHU-Test results and HIR/TD, and Sprinting during the final 15-minute period in this study (**Figure 5**) suggested that the CHU-Test results are correlated with the HIR during the final 15-minute period.

The results of this study suggested that the CHU-Test is a field test associated with the HIR during soccer matches. A limitation of this study, however, was the insufficient number of participants and the inclusion of male university soccer players only. Future studies would benefit by an increased number of participants and inclusion of professional and high school players to better grasp the relationship between CHU-Test results and HIR during soccer matches.

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