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ORIGINAL ARTICLE

Investigation of factors contributing to agility in prepubertal soccer players

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ABSTRACT

Agility is critical for soccer performance; however, limited studies have explored its underlying physical predictors in prepubertal athletes during development. This study aimed to investigate the factors contributing to agility in male prepubertal soccer players. We conducted a cross-sectional observational study on 52 male soccer players (chronological age: 10.6 ± 1.1 years; height: 141.4 ± 9.8 cm; body weight: 35.5 ± 9.8 kg). Reactive shuttle test (RST) was measured as an indicator of agility. Additional assessments included linear sprint, pro-agility test, squat jump, countermovement jump, rebound jump, and standing long jump. The RST also included measurement of reaction time at the initiation of movement. Furthermore, the change of direction (COD) deficit, calculated as the difference between the pro-agility test time and linear sprint time, was used to estimate the additional time required to change direction. Multiple regression analysis identified reaction time (β = 0.387), linear sprint time (β = 0.558), and COD deficit (β = 0.377) as significant predictors of RST time ($p < .05$), with an adjusted R^2 of .88. These findings suggest that, unlike in more physically developed athletes, reaction time, linear sprint speed, and COD deficit significantly contribute to agility in prepubertal soccer players.

Keywords: Performance analysis, Development, Agility, Maturity, Soccer, Reaction time, Change of direction.

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INTRODUCTION

Agility is a rapid whole-body movement, involving a change in velocity or direction in response to a stimulus (Sheppard and Young, 2006). In soccer, players frequently change direction, with approximately 700 changes of direction (COD) per match (Bloomfield et al., 2007). Agility tests can distinguish competitive levels in soccer players (Trajković et al., 2020; Andrašić et al., 2021; Ito et al.), underscoring its importance in performance.

Agility is a complex ability comprising multiple elements. Therefore, appropriate training tailored to each element is required to improve agility. Specifically, agility is related to cognitive-perceptual ability, linear sprint speed, additional time associated with COD deficits, lower limb strength and power, and reactive strength (Sheppard and Young, 2006; Ito et al.; Young et al., 2015).

These elements exhibit different developmental patterns with aging (Hirose et al., 2002; Tauchi et al., 2008; Papaiakovou et al., 2009). The timing of substantial development varies across elements and is likely influenced by inter-individual differences in maturation rate. Elements showing greater individual variability may serve as key determinants of agility. Therefore, during the developmental phase, factors contributing to agility may differ depending on age. Despite this, most previous studies investigating the factors contributing to agility in developing soccer players have focused on athletes aged 14–19 years (Ito et al.; Fiorilli et al., 2017; Veršić et al., 2020; Paprancova et al., 2024), with little insight gained regarding prepubertal players. To effectively plan agility-enhancing training for prepubertal soccer players, identifying the factors that contribute to agility in this age group is essential.

Previous studies have shown that the reactive shuttle test (RST), an agility test, can differentiate competitive levels among young soccer players, confirming its validity as an agility assessment tool for developing athletes (Ito et al.). Furthermore, the RST has demonstrated high intrasubject reliability in developing team sport athletes, indicating its adequacy as a reliable test of agility (Stojanović et al., 2019). Therefore, this study aimed to clarify the factors contributing to agility in prepubertal soccer players using the RST time as an indicator of agility.

MATERIAL AND METHODS

Procedures

This was a cross-sectional observational study. Measurements were performed on a dirt surface, and participants wore soccer cleats for all tasks. Body measurements were first performed on a stable surface. Height was measured to the nearest 0.1 cm using an ultrasonic height meter with a spirit level (Inlab, InBody Co., Ltd., South Korea), and body weight was measured to the nearest 0.1 kg using a digital scale (InBodyDial H20, InBody Co., Ltd., South Korea). After body measurements, the measurement procedures for all items were explained, and performance tests, including RST, linear sprint test, pro-agility test, squat jump (SJ), countermovement jump (CMJ), rebound jump (RJ), and standing long jump(SLJ) were conducted.

One practice trial was allowed before each test. Regarding the order of measurements, participants were categorized into two groups: one group performed the RST, pro-agility test, and linear sprint test first, while the other group performed SJ, CMJ, RJ, and SLJ first. After completing the initial measurements, the groups were swapped, and the remaining parameters were measured.

Participants

Participants were recruited from four prepubertal soccer teams. The content of this study was explained in writing to both the players and their guardians. After obtaining guardian consent, the participants participated voluntarily. Before commencing this study, an appropriate sample size was calculated using G*Power software (version 3.1.9.2, Universität Kiel, Düsseldorf, Germany). The effect size (f^2) was set to 0.61 based on values from previous studies with similar study designs using multiple regression analysis (Veršić et al., 2020). The significance level was set at .05, and the power ($1-\beta$) at 0.8. The number of independent variables was set to seven, reflecting the maximum number of predictors planned for the stepwise multiple regression analysis. Consequently, the required sample size was ≥32 participants. Ultimately, 52 prepubertal soccer players participated in this study (chronological age, 10.6 ± 1.1 years; height, 141.4 ± 9.8 cm; body weight, 35.5 ± 9.8 kg). This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Review Committee on Human Research of Waseda University (approval number: 2023-173).

Measures

Reactive shuttle test

The protocol for the RST is illustrated in Figure 1. Three lines were drawn at 5-yard intervals, and the participants started straddling the middle line. Two signal lights positioned in front of the participants provided visual stimuli. Participants were instructed to run in the direction of the illuminated light, step on the line, sprint to the opposite line, and return to the starting position as quickly as possible. A photocell timing system (Dashr, Dashr Motion Performance Systems, NE, USA) was used to record the RST time from the illumination of the signal light to the participant's crossing of the finish line. Reaction time was defined as the interval between the illumination of the light and participant's initial departure from the photocell sensor. Each participant performed two trials, and the best performance was recorded as the representative value.

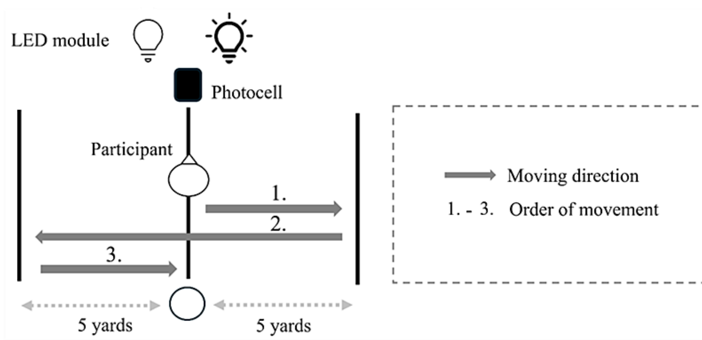

Figure 1. Protocol of reactive shuttle test.

Linear sprint

The protocol for the linear sprint test is shown in Figure 2. To maintain consistency in running distance and starting posture with the RST, participants began by straddling the start line in the same direction as their best RST trial. Photocell timing sensors (described above) were placed at the start, 5-yard, and 10-yard marks to record the time from start to finish. Each participant performed two trials. The shortest times recorded at the 5-yard and 10-yard marks were used as representative values.

Pro-agility test

The protocol for the pro-agility test is shown in Figure 3. The test followed the same procedure as the RST, except that no visual stimuli were presented. Participants were informed in advance to begin in the same direction as their best trial in the RST. A photocell timing system (described above) was used, and each participant performed two trials. The best time was recorded as the representative value. In this study, the COD deficit was used to assess the additional time required for directional changes. The COD deficit was calculated as follows (Ito et al.):

COD deficit = pro-agility test time - (5-yard time × 2) - 10-yard time.

Equation 1. Formula of COD deficit.

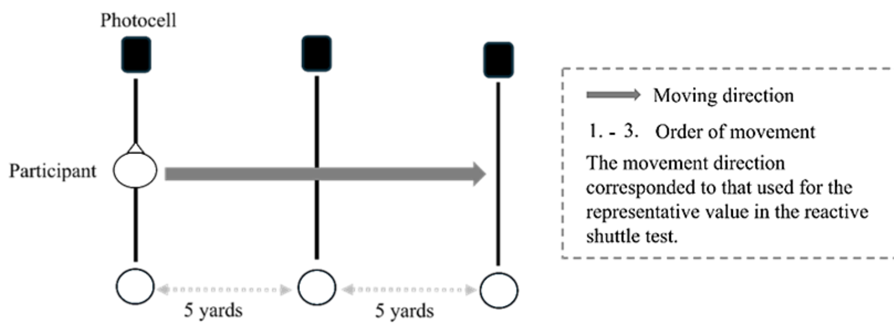

Figure 2. Protocol of linear sprint.

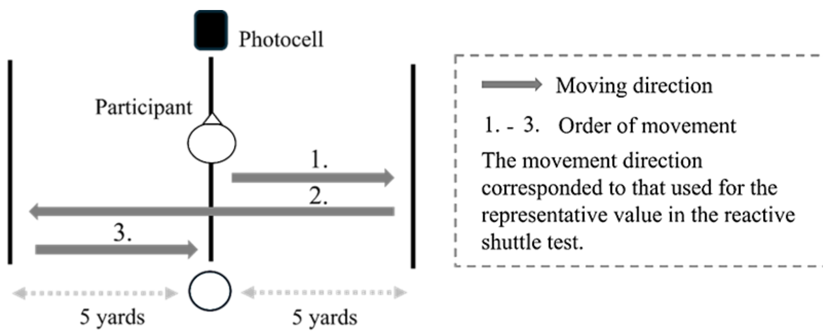

Figure 3. Protocol of pro-agility test.

Vertical jump tests

The SJ, CMJ, and RJ tests were performed using a velocity monitoring device (Enodepro, BM Sports Technology GmbH, Magdeburg, Germany), as previously described (Jimenez-Olmedo et al., 2023). The device was attached to the right hip, and participants kept both hands on their hips throughout the test to avoid contact with the device. For the SJ, participants jumped from a static position with knees bent at 90 °, and their jump heights were recorded. A skilled tester ensured that there was no countermovement; any trial exhibiting countermovement was repeated. CMJ was performed by quickly squatting down from a standing position, followed by a maximal effort jump. Both the SJ and CMJ tests were performed three times each, and the highest jump height was recorded. For RJ, the participants performed six consecutive jumps, aiming to maximize jump height while minimizing ground contact time. The reactive strength index (RSI) was calculated as follows, and the highest RSI among the six jumps was recorded:

RSI = jump height (m) / ground contact time (s)

Equation 2. Formula of RJ-RSI.

Standing long jump

Participants stood behind a marked line and performed a maximal forward jump. The jump distance was measured from behind the line to the back of the heel closest to the take-off line. The best of the two trials was recorded as the representative value. Measurements were performed to the nearest 1 cm using a measuring tape.

Statistical analysis

Prior to statistical analysis, all variables were transformed using natural logarithms to ensure the normality of residuals in the multiple regression model. Multiple regression analysis using the stepwise method was performed with RST time as the dependent variable. Independent variables included reaction time, 10-yard sprint time, COD deficit, SJ height, CMJ height, RJ-RSI, and SLJ distance. For the multiple regression analysis, the coefficient of determination (R^2), which represents the overall contribution of the independent variables, and the standardized partial regression coefficients (β) for each independent variable, along with their significance probabilities (p-values), were calculated. Multicollinearity was evaluated using the Variance Inflation Factor (VIF) and tolerance as indicators; multicollinearity was considered present if VIF was ≥5 or tolerance was ≤0.2. To validate the regression model, the normality of residuals was confirmed using the Kolmogorov–Smirnov test. A significance level $p < .05$ was used to assess the significance of independent variable coefficients and the normality of residuals. All statistical analyses were conducted using R software (version 4.5.1, R Core Team, Vienna, Austria) in RStudio.

RESULTS

Contributing factors related to the reactive shuttle test

Information on all measurement variables is presented in Table 1. Multicollinearity was not observed in the multiple regression analysis, as all VIF values were below 5 and tolerance values exceeded 0.2. The normality of residuals was also satisfied. The results of the multiple regression analysis are presented in Table 2. Reaction time, COD deficit, 10-yard sprint time, and SJ height were selected as explanatory variables for RST time. Among these, reaction time, COD deficit, and 10-yard sprint time had statistically significant coefficients (β) ($p < .05$). The adjusted R^2 for the entire set of explanatory variables was .88.

Table 1. Background information of participants.

Variables	**Mean ± SD**
RST time (s)	6.61 ± 0.48
Reaction time (s)	0.83 ± 0.21
Pro-agility test time (s)	5.76 ± 0.38
5-yard sprint time (s)	1.24 ± 0.08
10-yard sprint time (s)	2.17 ± 0.13
COD deficit (s)	1.11 ± 0.22
SJ height (cm)	28.1 ± 5.6
CMJ height (cm)	29.1 ± 5.1
RJ-RSI (m/s)	1.49 ± 0.37
SLJ (cm)	158 ± 18

Note. RST time, reactive shuttle test time; COD deficit, change-of-direction deficit; SJ height, squat jump height; CMJ height, countermovement jump height; RJ-RSI, rebound jump-reactive strength index; SLJ, standing long jump.

Table 2. Results of multiple regression analysis.

Variables	**Standardized β**	**Adjusted R^2**
Reaction time (s)	0.387	
10-yard time (s)	0.558	.88
COD deficit (s)	0.377	
SJ height (cm)	-0.077	

Note. COD deficit, change-of-direction deficit, SJ height, and squat jump height.

DISCUSSION

This study aimed to identify factors that contribute to agility in prepubertal soccer players. Multiple regression analysis revealed that reaction time, 10-yard sprint time, and COD deficit were significant explanatory variables for RST time. These variables collectively accounted for 88% of the variance in RST time, indicating a strong relationship with RST performance.

Reaction time showed a particularly high contribution to RST time. Notably, previous studies have reported no significant correlation between RST and reaction time in high school (age: 16‒18 years) male soccer players (Ito et al.), which differs from our findings. This discrepancy is likely due to the greater interindividual variability in reaction time observed among the prepubertal participants in this study. The standard deviation for reaction time among prepubertal participants in this study was 0.21 s, compared to 0.05–0.07 s reported in high school soccer players (Ito et al.), indicating larger individual differences in this study. In prepubertal soccer players, where individual differences in reaction time are substantial, these variations may reflect in agility performance. Since the prepubertal age is a period of significant development in reaction time (Hirose et al., 2002), individual differences in reaction time are likely substantial owing to variations in the rate of this development. Considering both agility enhancement and trainability, training focused on reaction time, especially with external stimuli, may be highly effective in prepubertal soccer players.

Linear sprint time (10-yard sprint time) was also selected as a significant explanatory variable and showed the highest contribution to RST time. Studies on adult athletes suggest a weak relationship between agility and linear sprint performance (Altmann et al., 2021) and have observed no significant correlation between RST and linear sprint time in high school soccer players (age: 16‒18 years) (Ito et al.). Therefore, our findings differ from those of previous studies. Similar to reaction time, this difference may be explained by the larger individual variability among the participants. The standard deviation for 10-yard sprint time in high school soccer players was 0.06-0.07 s, whereas it reached 0.13 s in the prepubertal soccer players in this study. This suggests that pure linear sprint speed may be a more influential factor on agility when there is greater variability in this ability. Furthermore, external stimuli can affect starting posture, hindering an optimal start (Mornieux et al., 2014; Kameda et al., 2019). In linear sprint tests, the absence of external stimuli allows an individual to start in an optimal posture. Conversely, agility tests require responses to external stimuli, which prevents starting in an ideal position. This fundamental difference weakens the correlation between agility and linear sprint performance (Ito et al.). Thus, athletes of high school age and older must quickly control their posture after reacting to external stimuli and establish an optimal movement posture (Ito et al.). In contrast, in younger age groups with large individual differences in linear sprinting ability, such as prepubertal soccer players, pure movement speed, rather than postural control ability, may be the primary factor influencing agility. Therefore, training that enhances linear sprint performance, such as plyometrics, could be an effective means of improving the agility in prepubertal soccer players (Niering et al., 2025).

The COD deficit was also selected as a significant explanatory variable for RST time. The RST involves multiple 180° COD, making it closely related to COD ability. Previous studies on high school soccer players also reported a significant positive correlation between RST time and COD deficits (Ito et al.), consistent with our findings. COD deficit may serve as a useful indicator of agility across different age groups. Moreover, training targeting the COD technique reduce COD deficits (Dos'Santos et al., 2019), suggesting that technical COD training can contribute to improvements in agility among prepubertal soccer players.

This study had some limitations. First, it was limited to male prepubertal soccer players. Based on the findings of this study, the factors contributing to agility differ depending on age. Therefore, as these contributing factors may vary based on individual characteristics, caution should be exercised when applying the present findings to populations with different characteristics, such as those of different sexes or sports. Second, although individual differences in biological maturation exist during development, this study did not account for this factor. Therefore, these results should be interpreted with caution. Future studies should consider maturity when examining factors related to agility.

CONCLUSIONS

This study aimed to identify the factors related to agility in prepubertal soccer players. The results indicate that reaction time, linear sprint ability, and COD deficit are significant contributors, collectively explaining a substantial portion of agility performance in this population.

AUTHOR CONTRIBUTIONS

The individual contributions of each author are as follows: conceptualization: H.I. and K.H.; methodology: H.I. and K.H.; formal analysis: H.I. and Y.N.; investigation: H.I. and Y.N.; data curation: H.I.; writing—original draft preparation: H.I.; writing—review and editing: K.H. and T.A.; visualization: H.I.; supervision: K.H. and T.A.; project administration: K.H. and T.A. All authors have read and approved the final version of the manuscript. All authors agree to the submission of this manuscript for publication in the Scientific Journal of Sport and Performance (SJSP).

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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