

Factors influencing youth academy promotion in Japanese soccer: Mediation analysis of biological maturation, sprint ability, and match play ratio

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Abstract

Promotion from under-15 (U-15) to U-18 categories is a decisive selection point in Japanese soccer academies; however, the structural process underlying this decision remains unclear, and evaluations conducted during the adolescent growth spurt may favor early-maturing players. In this study, the structural relationship between biological maturation, physical performance, and youth academy promotion was investigated among Japanese soccer players, with particular attention to match play ratio as a potential mediating variable. Participants included 60 male U-15 players from a J-League youth academy, and they were categorized into a promotion group ($n = 32$) and a nonpromotion group ($n = 28$). Measurements included skeletal muscle mass, maturity offset estimated by a Japanese-specific equation, sprint times (10 and 30 m), jump performance, and match play ratio (actual playing time divided by the total possible playing time). Group differences were examined using independent t -tests, and four logistic mediation models were tested. The promotion group showed significantly higher muscle mass and match play ratio and significantly faster sprint times than the nonpromotion group. No significant difference in biological maturation was observed, although effect sizes indicated a small-to-medium difference. Although biological maturation showed a limited indirect effect, logistic mediation analysis revealed that, a significant mediation path was identified from 30-m sprint time to promotion via match play ratio (indirect effect = -2.73 , $p < 0.01$). These findings indicate that sprint ability is a primary determinant of coach selection for match participation, which subsequently influences promotion decisions. The results of this study emphasize the need for long-term development strategies that account for individual differences in physical maturation to ensure a fair and effective talent identification process.

Key Words: Talent identification, Maturity offset, Adolescent athletes, Coach selection, Playing time exposure, Long-term athlete development

Introduction

The youth development environment in Japanese soccer is characterized by two highly competitive parallel pathways, namely, club-based academies (J-League youth systems) and school-based clubs (high school teams). Although both routes serve as primary gateways to professional careers, J-League academies provide a significant advantage by maintaining a consistent coaching philosophy across the under-12 (U-12), U-15, and U-18 categories. The concept of long-term athlete development (LTAD), which emphasizes the alignment of training and competition demands with the stage of growth and maturation of each athlete, has become a guiding framework for such integrated youth systems internationally (Balyi & Hamilton, 2004). Previous research has highlighted that such integrated systems facilitate the step-by-step acquisition of technical and tactical skills within the LTAD framework (Lloyd & Oliver, 2012). Backed by the mandatory club licensing system, Japanese J-League academies have established comprehensive education programs that are directly linked to their top teams, thereby maintaining highly competitive standards through nationally unified leagues. Despite this structural sophistication, the criteria by which players are retained or released at key transition points remain dependent on coach judgment, and the relative weight of physical, maturational, and performance-based factors in these decisions has rarely been examined empirically in the Japanese context. Although school-based clubs play a vital role in education and character formation, academy environments provide a setting closer to professional standards with regard to specialized physical training and data-driven evaluation systems, notwithstanding the triennial changes in coaching structures common in schools. In particular, promotion evaluation from U-15 to U-18 represents a critical “life crossroads,” determining whether a player continues within the professional academy system or transitions to a school-based career.

The U-15 period is consistent with the peak of the adolescent growth spurt, during which individual differences in height, muscle mass, and skeletal maturity expand significantly (Malina et al., 2004; 2015). Thus, conducting promotion evaluations during this phase of high developmental variance may favor early-maturing players, which may limit growth opportunities for late-maturing athletes. Therefore, a detailed verification of the structure of promotion evaluations at the U-15 stage is essential for reassessing the fairness and validity of talent identification within the Japanese development system.

In developing athletes, biological maturation profoundly influences physical performance. Maturity progression is associated with multiple physical characteristics, including muscle mass, sprint capacity, and power output (Philippaerts et al., 2006; Radnor et al., 2018), with early maturers often possessing relative physical advantages within their age groups (Figueiredo et al., 2009). The period during which maturation most strongly amplifies interindividual differences in anthropometric and fitness characteristics has been shown to coincide with the U-14 to U-15 age range, precisely when many academies conduct decisive selection (Towlson et al., 2018). This advantage extends beyond physical ability, potentially influencing the subjective evaluations and match selections of coaches. Cripps et al. (2016) showed that coaches perceive early-maturing players as more “competitively superior” or “match-ready.” Similarly, Williams et al. (2020) highlighted the risk of maturation-driven bias in early talent selection, and Leyhr et al. (2021) reported that objective and subjective (coach-rated) performance assessments are systematically confounded by relative age and maturity-related differences. Hill et al. (2021) also found that coaches’ evaluations of match performance were significantly associated with players’ biological maturity status, underscoring how readily maturation can distort the perception of talent. Such findings indicate that what coaches interpret as superior “potential” may partly reflect transient maturational advantage rather than enduring ability (Barraclough et al., 2024). Conversely, late-maturing players may be disadvantaged in short-term evaluations because of delayed physical development, thereby facing restricted opportunities for selection and match participation (Hill et al., 2020; Lovell et al., 2015). To address the abovementioned issues, bio-banding, which refers to reorganizing categories based on biological maturity, has been introduced in Europe to create equitable development and selection systems (Cumming et al., 2017). Empirical trials of bio-banded competition have shown that grouping players by maturity rather than chronological age alters physical and technical–tactical demands and provides developmental benefits for early- and late-maturing players (Cumming et al., 2018; Lüdin et al., 2022). However, in Japan, school-based and club-based systems remain dependent on chronological age groups, and the extent to which maturation affects selection and evaluation has not been verified.

Furthermore, sprint ability is a crucial physical attribute in modern soccer. Short-distance sprints are involved in many decisive match actions, such as escaping opponents to create goal-scoring opportunities or delivering decisive passes (Faude et al., 2012), which significantly affect player evaluation and positional suitability. Acceleration and deceleration movements occur more frequently than changes of direction (COD) during matches (Dellal et al., 2011), which account for a large portion of the total energy expenditure (Osgnach et al., 2010). Anthropometric and physical profiles, including sprint and power characteristics, also differ by playing position, making such attributes relevant to talent identification and positional suitability (Lago-Peñas et al., 2011). Consequently, sprint ability is a central element of youth player evaluation; however, its development is dependent on maturation (Philippaerts et al., 2006). This relationship indicates a complex interconnected structure between maturity, sprint ability, and competitive evaluation.

However, few studies, either domestically or internationally, have integrated these relationships to clarify their association with promotion. In Japanese academy settings, low promotion rates and the lack of transparency in the selection process have long been identified as challenges. Only approximately 30%–40% of U-15 academy players have been successfully promoted to U-18 (JFA, 2022), many of whom were forced to transition to high school soccer or other clubs. Subjective coaching judgments often play a significant role in this process, which sometimes leads to a lack of shared evaluation criteria among players, parents, and coaches (JFA, 2021). The match play ratio, which refers to the proportion of actual playing time, is a critical indicator reflecting a coach’s trust and evaluation (Cumming et al., 2017), and a tendency for physically superior players to be prioritized for selection has been noted. Accumulated match exposure is an important developmental outcome: retrospective and longitudinal analyses have linked physical fitness and motor coordination characteristics to subsequent dropout, contract status, and first-team playing time (Deprez et al., 2015), and match-running performance has been shown to differentiate retained from released academy players (Saward et al., 2016). Therefore, a multistage process is hypothesized: “maturity → physical characteristics → match play ratio → promotion.” In this process, early maturers leverage physical advantages to increase match involvement, leading to higher promotion evaluations. However, few studies have statistically modeled such structural chains or verified them through mediation effects.

Most existing studies have examined maturity, physical ability, or technical skill individually in relation to promotion, with limited research systematically explaining the mechanism by which these factors interact to influence selection. In particular, few attempts have positioned match play ratio as a mediating variable to integrally explain the relationship between maturity and promotion. In this regard, mediation analysis is considered as an effective method for capturing the promotion evaluation process realistically and multidimensionally by simultaneously verifying multiple causal pathways.

Therefore, this study aims to compare the physical characteristics and athletic performance of promoted and nonpromoted players in a J-League U-15 academy and to clarify the mechanism by which sprint ability and match play ratio, originating from biological maturity, affect promotion. In addition, logistic regression–based mediation analysis was used to verify the existence of a multistage relationship: maturity → sprint ability → match play ratio → promotion. The findings of this study will provide insights into the structural characteristics of the U-15 promotion process and significant implications for building fair and sustainable development systems that account for individual differences in maturation.

Material & methods

Participants

A total of 60 male soccer players (height: 168.8 ± 5.7 cm; body mass: 58.2 ± 6.2 kg) belonging to a J-League junior youth academy (U-15) were included in this study. The subjects were divided into two groups: a promotion group ($n = 32$; height: 170.5 ± 4.9 cm; body mass: 59.6 ± 5.4 kg) consisting of players who were promoted to the youth team (U-18) and a nonpromotion group ($n = 28$; height: 167.3 ± 5.9 cm; body mass: 57.0 ± 6.8 kg) consisting of players who were not promoted. All data were anonymized by the club before being provided to the authors. An opt-out procedure was implemented to ensure that the participants had the opportunity to refuse data provision. This study was approved by the Ethics Committee of International Budo University (Approval No. 24001).

Procedure/test protocol/measure/instruments

Anthropometric and physical fitness measurements were conducted in November of the players' third year of junior high school.

Anthropometric measurements:

Height, body mass, sitting height, and skeletal muscle mass were measured. Skeletal muscle mass was determined using a multifrequency bioelectrical impedance analysis device (InBody 270; InBody Co., Ltd., Seoul, Korea). The participants wore light clothing and were barefoot, with strenuous exercise being restricted prior to measurement.

Biological maturation:

Maturity status was expressed as maturity offset, which is defined as the estimated temporal distance (in years) from the age at peak height velocity. The maturity offset approach was originally established by Mirwald et al. (2002). In the present study, maturity offset was calculated using a maturity offset estimation equation developed by Murayama et al. (2023), which was specifically designed for the physical characteristics of Japanese youth.

Physical fitness tests:

Tests were performed on an artificial turf soccer field with participants wearing soccer cleats. A standardized warm-up was conducted before the following tests:

10- and 30-m sprints: Linear sprint capacity was evaluated using 10- and 30-m sprint tests starting from a standing position with maximum effort. Movements were captured laterally using an iPad (240 fps), and times were calculated through frame-by-frame analysis. The validity of using high-speed video for split times has been previously established.^[1]

COD: A "5 m $\times$ 3 shuttle COD run" was employed, in accordance with the JFA Academy standards. The participants performed three CODs between markers set 5 m apart, with 1.6-m poles installed at the turns. The total time was calculated using 240-fps video analysis.^[1]

Standing long jump: The participants jumped forward from a standing position with feet shoulder-width apart. The distance from the take-off line to the heel at the landing point was recorded from the better of two trials.^[1]

Vertical jump: Jump height was evaluated using countermovement jumps recorded at 240 fps. Flight time (t) was determined by identifying take-off and landing frames. Jump height (h) was estimated as follows:

The flight-time method using a 240-fps video has shown high validity compared with force plate measurements.

Match play ratio: This variable was defined as the percentage calculated by dividing the cumulative time a player actually participated in matches by the total possible match time available in the U-15 category from the time of joining the club until the date of physical measurement.

Data collection and statistical analysis

Independent t -tests were used to compare measurements between the promotion and nonpromotion groups. Pearson's correlation analysis was conducted to examine the relationship between match play ratio and physical/athletic indicators. Furthermore, logistic mediation analysis was performed using match play ratio as a mediating variable to verify the following four models:

Model 1: maturity $\rightarrow$ sprint ability $\rightarrow$ promotion

Model 2: maturity $\rightarrow$ muscle mass $\rightarrow$ sprint ability $\rightarrow$ promotion

Model 3: sprint ability $\rightarrow$ match play ratio $\rightarrow$ promotion

Model 4: maturity $\rightarrow$ match play ratio $\rightarrow$ promotion

Linear regression was used for mediation, and logistic regression was used for the final outcome (promotion). Indirect effects ($a \times b$), direct effects (c'), and total effects (c) were calculated. The statistical significance level was set at 5%.

Results

The results of the t -tests comparing the groups are presented in Table 1. The promotion group showed significantly higher values in match play ratio ($t = 5.18$, $p < 0.001$, $d = 1.30$), skeletal muscle mass ($t = 2.41$, $P < 0.05$, $d = 0.61$), and standing long jump ($t = 3.36$, $p < 0.01$, $d = 0.86$) than the nonpromotion group. Furthermore, the promotion group showed significantly faster times in the 10-m sprint ($t = -3.09$, $p < 0.01$, $d = 0.79$) and 30-m sprint ($t = -3.15$, $p < 0.01$, $d = 0.81$). No significant differences were observed in biological maturation ($t = 1.89$, $p = 0.063$, $d = 0.47$), COD ($t = -1.89$, $p = 0.064$, $d = 0.49$), or vertical jump ($t = 1.84$, $p = 0.072$, $d = 0.47$).

The results of correlation analysis between variables are shown in Table 2. Promotion outcome was significantly correlated with match play ratio ($r = 0.55$, $p < 0.001$), standing long jump ($r = 0.40$, $p < .01$), 30-m sprint ($r = -0.38$, $p < 0.01$), 10-m sprint ($r = -0.37$, $p < 0.01$), and skeletal muscle mass ($r = 0.29$, $p < 0.05$). No significant

correlations were found between promotion and biological maturation ($r = 0.23, p = 0.063$), COD, or vertical jump. In addition, match play ratio was significantly correlated with 30-m sprint ($r = -0.37, p < 0.01$) and 10-m sprint ($r = -0.35, p < 0.01$), whereas no significant correlations were observed with other variables. Logistic mediation analysis revealed the following findings:

Model 1 (maturity → sprint ability → promotion)

The initial model examined whether 30-m sprint time mediated the relationship between biological maturation and promotion. The effect of maturation on 30-m sprint time was not statistically significant ($a = -0.08$, n.s.). However, 30-m sprint time was a significant predictor of promotion ($b = -4.43, p < 0.01$). When controlling for 30-m sprint time, the direct effect of maturation on promotion was not significant ($c' = 1.02$, n.s.). Consequently, the overall indirect effect (indirect effect = 0.34) was not significant because of the lack of a significant relationship between maturation and 30-m sprint time.

Model 2 (maturity → muscle mass → 30-m sprint → promotion)

Maturity had a strong positive effect on skeletal muscle mass ($a1 = 5.25, p < 0.001$). However, the subsequent effect of muscle mass on 30-m sprint time was not statistically significant ($a2 = -0.01$, n.s.). Although 30-m sprint time remained a significant predictor of promotion within this multistage model ($b = -4.35, p < 0.01$), the direct effect of maturity on promotion was not significant ($c' = 0.65$, n.s.). Consequently, the overall indirect effect from maturity to promotion via muscle mass and 30-m sprint time was not significant because of the broken pathway between muscle mass and 30-m sprint.

Model 3 (sprint ability → match play ratio → promotion)

The primary mediation model examined whether match play ratio mediated the relationship between 30-m sprint time and promotion. The 30-m sprint time significantly predicted match play ratio ($a = -45.95, p < 0.01$), indicating that faster players received more playing time. Furthermore, match play ratio was a significant predictor of promotion ($b = 0.06, p < 0.01$). When controlling for match play ratio, the direct effect of 30-m sprint time on promotion became nonsignificant ($c' = -2.94$, n.s.). The overall indirect effect was statistically significant (indirect effect = -2.73), indicating a full mediation effect. Therefore, sprint ability influences promotion primarily through increased opportunities for match participation.

Model 4 (maturity → match play ratio → promotion)

The final model examined whether match play ratio mediated the relationship between biological maturation and promotion. The effect of maturation on match play ratio was not statistically significant ($a = 5.24$, n.s.), indicating that advanced maturity did not directly result in more playing time. As observed in previous models, match play ratio positively predicted promotion ($b = 0.07, p < 0.01$). When controlling for match play ratio, the direct effect of maturation on promotion was not significant ($c' = 1.21$, n.s.). Consequently, the indirect effect (indirect effect = 0.36) was not supported because of the lack of a significant relationship between maturation and match play ratio.

Table 1. Comparison of anthropometric and physical fitness variables between the promotion and nonpromotion groups

Variables	Promotion group ($n = 32$)		Nonpromotion group ($n = 28$)		p	t	ES
	Mean	SD	Mean	SD			
Biological maturation (years)	2.37	0.46	2.11	0.59		1.89	0.47
Match play ratio (%)	71.99	17.47	46.37	21.33	***	5.18	1.30
Skeletal muscle mass (kg)	46.50	3.41	44.15	4.18	*	2.41	0.61
10-m sprint (s)	2.03	0.08	2.10	0.10	**	-3.09	0.79
30-m sprint (s)	4.68	0.17	4.83	0.21	**	-3.15	0.81
Change-of-direction (s)	4.26	0.13	4.35	0.22		-1.89	0.49
Vertical jump (cm)	42.81	4.21	40.21	6.41		1.84	0.47
Standing long jump (cm)	229.04	17.05	215.21	15.06	**	3.36	0.86

ES: effect size (Cohen's d). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2. Correlation matrix between variables

	Promotion	Biological maturation	Match play ratio	Skeletal muscle mass	10-m sprint	30-m sprint	Change-of-direction	Vertical jump	Standing long jump
Promotion	-	0.23	0.55***	0.29*	-0.37**	-0.38**	-0.24	0.23	0.40**
Biological maturation		-	0.13	0.69***	-0.14	-0.20	-0.05	0.36**	0.38**
Match play ratio			-	0.11	-0.35**	-0.37**	-0.08	0.09	0.09
Skeletal muscle mass				-	-0.03	-0.21	-0.28*	0.26*	0.51***
10-m sprint					-	0.82***	0.26*	-0.49***	-0.34**

30-m sprint	-	0.51***	-0.62***	-0.48***
Change-of-direction			-0.31*	-0.28*
Vertical jump			-	0.69***
Standing long jump				-

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

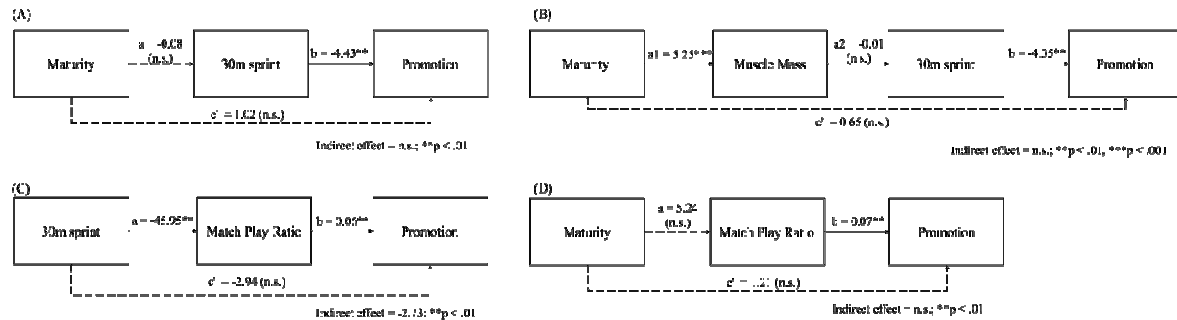


Figure 1. Path diagrams of mediation analyses evaluating the factors influencing youth academy promotion. The solid lines indicate statistically significant pathways, whereas dashed lines indicate nonsignificant pathways. (A) Model 1:

The mediation pathway from biological maturation to promotion via 30-m sprint time. (B) Model 2: The multistage mediation pathway from maturation to promotion via skeletal muscle mass and 30-m sprint time. (C) Model 3: The primary significant mediation pathway from 30-m sprint time to promotion via match play ratio. (D) Model 4: The mediation pathway from maturation to promotion via match play ratio. *** $p < 0.001$, ** $p < 0.01$; n.s. indicates not significant.

Discussion

In the present study, the multifaceted relationship between biological maturation, sprint ability, skeletal muscle mass, and match play ratio in relation to youth academy promotion was investigated among J-League U-15 players. Furthermore, mediation analysis was utilized to verify the potential pathways through which maturity and sprint ability influence promotion via match involvement. Our fundamental analysis revealed that the promotion group exhibited significantly higher values in skeletal muscle mass, standing long jump, and 10-m/30-m sprint times than the nonpromotion group, with moderate-to-large effect sizes. Notably, match play ratio showed the strongest association with promotion, indicating that a coach's selection for match participation is a critical determinant of promotion decisions.

Regarding the influence of biological maturation, our findings provide a nuanced perspective compared with numerous previous studies. In developing athletes, the progression of maturity is often closely linked to physical characteristics such as muscle mass and sprint capacity (Malina et al., 2004; Philippaerts et al., 2006). Consequently, European studies have frequently pointed out the existence of a “maturity bias,” where early-maturing players often gain a competitive advantage and favorable evaluations within their chronological age groups (Cumming et al., 2017; Figueiredo et al., 2009; Hill et al., 2020). However, the current study found no statistically significant difference in biological maturation (corrected maturity offset) between the promotion and nonpromotion groups ($P = 0.063$). Given the limited sample size, in this specific Japanese U-15 cohort, biological maturation did not directly dictate the coaches' subjective impressions or competitive judgments to the extent seen in other contexts. This lack of severe maturity bias may indicate that the club's evaluation criteria prioritize technical, tactical, or functional physical traits over physical size or early maturation.

Consistent with this finding, mediation analysis did not clearly support the pathway from maturity to promotion via sprint ability (Model 1). Maturity showed only a weak relationship with sprint performance, and the indirect effect was not statistically significant. Therefore, physical differences resulting from maturation do not necessarily translate directly into functional sprint performance on the pitch. In the multistage model of maturity → muscle mass → sprint ability → promotion (Model 2), although maturity exerted a strong positive influence on muscle mass, no clear evidence that muscle mass dictated sprint ability was found. This finding is consistent with prior research indicating that sprint performance during development depends more on neuromuscular development, motor coordination, and reactive strength (SSC function) than on absolute muscle mass alone (Radnor et al., 2018). Therefore, although muscle mass characterizes the promotion group as a physiological advantage, its contribution as a direct mediating factor for sprinting and subsequent promotion is limited.

The most prominent and robust result of this study was the pathway from sprint ability → match play ratio → promotion (Model 3). Players with superior 30-m sprint times were more frequently selected for official matches, and the indirect effect of this match experience leading to promotion was highly significant. This pathway is consistent

with previous research emphasizing the importance of sprinting, acceleration, and deceleration capacities in the tactical demands of modern soccer (Dellal et al., 2011; Osgnach et al., 2010). In particular, coaches utilize functional sprinting ability, which refers to the capacity to execute high-intensity actions during a game, as a primary criterion for match selection. The playing time granted serves as an opportunity for players to show their tactical understanding and psychological resilience under competitive pressure, which ultimately drives the promotion decision.

Furthermore, as shown in Model 4, neither the direct effect of maturity on match play ratio nor the overall indirect effect on promotion was statistically significant. Therefore, biological maturation alone does not guarantee increased playing time or promotion. This finding strongly reinforces the result of Model 3: coaches do not select players based on their physical maturity but rather strictly on their functional sprint ability shown on the pitch. Such an emphasis on functional performance, rather than physical size, may serve as an effective approach to mitigate maturity biases and prevent the premature dropout of late-maturing talent (Lovell et al., 2015).

Although promotion at the U-15 stage involves complex hierarchical relationships between maturity, physical attributes, and match involvement, a clear mediation relationship was established exclusively for the “sprint ability → match play ratio → promotion” pathway. The uniqueness of this study lies in demonstrating that actual on-field performance capabilities (sprinting) and the subsequent accumulation of match experience outweigh the direct advantages of biological maturation in the decision-making process for youth promotion in this environment. Given the limited mediation pathways for maturity, future research should verify the dynamics of physical ability, tactical evaluation, and match experience using larger scale longitudinal data across multiple academies.

Conclusions

This study multifacetedly examined the relationship between physical characteristics, athletic performance, match play ratio, and youth promotion among players in a J-League U-15 academy. The results indicated that the promotion group was significantly superior to the nonpromotion group with regard to skeletal muscle mass, standing long jump, and 10-m/30-m sprint times, whereas no significant difference was found in biological maturation (corrected maturity offset), although a small-to-medium effect size was observed. In particular, sprint performance showed medium-to-large effect sizes. Furthermore, match play ratio exhibited the strongest association with promotion and a strong correlation with sprint ability.

The statistical significance of the “sprint ability → match play ratio → promotion” pathway is the key finding of this study, which was identified through mediation analysis. This pathway is consistent with previous research highlighting the importance of short-distance sprinting in modern soccer, and it supports a structure where coaches evaluate acceleration/deceleration capacities, leading to match selection and subsequent promotion. Conversely, the impact of biological maturation on promotion was highly limited. No significant indirect pathway was observed from maturation via match play ratio, which indicates that maturation alone does not dictate match playing time or promotion outcomes. However, given the strong relationship between maturity and muscle mass, the need for long-term development strategies that consider developmental stages remains important, ensuring late maturers are not prematurely disadvantaged. In summary, an evaluation structure centered on sprint ability and official match involvement exists for youth promotion, with physical development related to biological maturity partially influencing this background. Consequently, long-term and equitable development policies considering developmental stages are necessary.

Study limitations

This study has several limitations. First, given the cross-sectional design of this study, strict causal relationships between maturity, physical ability, match play ratio, and promotion cannot be definitively identified; mediation analysis remains an estimation of a hypothetical causal structure. Thus, future longitudinal studies are necessary to track temporal changes in maturity progression and athletic development.

Second, although the match play ratio is a beneficial indicator of coach evaluation, it does not fully control for diverse factors such as positional characteristics, tactical roles, injuries, or team circumstances. Multidimensional evaluations, including technical, tactical, and cognitive indicators, are necessary to comprehensively understand the mechanism by which match play ratio serves as a mediator.

Third, the physical performance indicators measured were limited, and such indicators did not include high-performance metrics that are critical to modern soccer, such as repeated acceleration/deceleration ability, high-speed running, or on-field positioning and decision speed. Thus, analyzing match data, including these indicators, remains a task for future research.

Fourth, although corrected maturity offset was used as the maturity indicator, various estimation methods exist, each with its own measurement errors and scope. Whether similar results would be obtained using different estimation methods remains unclear.

Finally, the subjects were limited to U-15 players from a specific J-League academy, where club policies or regional characteristics may have influenced promotion criteria. Therefore, comparative studies targeting other clubs and regions are necessary to verify the external validity of these findings.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by KENSUKE SUZUKI, YUTAKA KATO, and RYOICHI MURAYAMA. The first draft of the manuscript was written by KENSUKE SUZUKI, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

The Use of Generative AI statement

During the preparation of this work, the authors used a generative AI-assisted tool (Gemini) in order to check grammar, spelling, and linguistic clarity. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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