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RESEARCH ARTICLE

Observational Study of Growth-Related Knee Pain in Japanese Footballers Aged 12–15 Years: A Subsequent Series Following Children Aged 8–12 Years

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ABSTRACT

This is a subsequent series of studies that examined the factors for growth-related injuries in children aged 8–12 years. We aimed to explore factors associated with growth-related knee pain (GRNP) in Japanese footballers aged 12–15 years. A total of 600 data (200 football players in 7–9th grades) were collected from their parents. Clinical characteristics (age, height, and weight), sports-specific variables (dominant leg, position, and surface), weekly training volume (total days and hours of football), and experience of GRKP (e.g., Osgood–Schlatter disease) within the past 1 year were assessed using a web-based questionnaire. Independent *t*-tests and chi-square tests were used to investigate the difference between groups with and without GRKP. Logistic regression analyses were also performed to explore risk factors for youth athletes. Additionally, a receiver operating characteristic curve was constructed for the variables used in the logistic regression model. Among junior high school footballers in Japan, 21.0% had experience with GRNP in the past 1 year. Weekly training hours were significantly and positively associated with GRNP (odds ratio, 1.047; 95% confidence interval, 1.016–1.079). The optimal cut-off value for training hours per week was 12.5 h, with low-to-moderate sensitivity (44.4%) and specificity (73.8%). However, clinical and sport-specific characteristics in Japanese footballers aged 12–15 years were not identified as risk factors for recent GRNP. To decrease the risk of GRNP in young Japanese footballers, controlling training volume, which combines adequate recovery or introducing multi-sports events, may be a key strategy for injury prevention.

Keywords: Growth-related injury, prevention, training volume, youth footballers

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1. Introduction

To proceed with injury prevention strategically, understanding the risk factors and mechanisms of injuries in each sport and playing category is essential. Risk factors are divided into intrinsic (i.e., age, sex, body composition, and leg dominance) and extrinsic (i.e., environment and surface) components, which render athletes susceptible to injury. Furthermore, the mechanism of sports injury is used to describe the inciting event (i.e., playing/sports situation) directly associated with the onset of injury. Exposure to matches and training (total load) have been introduced as practical examples of inciting events for lower leg stress fractures in football (Bahr & Krosshaug, 2005). This scenario is what is called "overuse injury."

Football is popular among many generations worldwide; however, players of different ages and circumstances are not at equal risk of injuries. Children and adolescents are not the same as adults, and young football players often suffer from growth-related injuries (Faude *et al*., 2013; Juch *et al*., 2023; Rössler *et al*., 2016). Apophyseal injuries are common in young footballers; however, the incidence of different apophyseal injuries varies substantially, depending on the location and age group. For

example, the peak incidence of foot-ankle time-loss apophyseal injuries (e.g., severe disease) occurs in patients aged <11 years, whereas those of the knee (e.g., Osgood–Schlatter disease) occur in patients aged <14 years (Materne *et al*., 2022). Another study also showed similar results that Osgood–Schlatter and Sever's diseases had their peak prevalence in football players <13–14 years and <11 years, respectively (Le Gall *et al*., 2006; Price *et al*., 2004). Furthermore, knee overuse injuries, including the Osgood–Schlatter disease, for children aged 9–14 years represented the greatest burden on better performance, and complications were more likely reported by older players (12–14 years) than younger players (9–11 years) (Leppänen *et al*., 2019). Therefore, young footballers aged 13–14 years are the main targets for the prevention of growth-related knee injuries.

Recently, factors associated with growth-related knee pain (GRNP) in Japanese footballers <12 years have been explored (Iwame *et al*., 2019; Sasaki *et al*., 2023). Data from East Asia are valuable because almost all epidemiological reports on growth-related or overuse conditions in children are from Western countries (Gaulrapp & Nührenbörger, 2022; Materne *et al*., 2022; Post *et al*., 2020; Rössler *et al*., 2018). Additionally, previous studies in Japan could not target the main age at which GRNP occurs most frequently (approximately 13–14 years old), although they could identify the target age for growth-related heel pain (around 11 years old). Therefore, this study aimed to explore the factors associated with GRNP in Japanese footballers aged 12–15 years as a study series following a previously published study in children aged 8–12 years old (Sasaki *et al*., 2023). In the cultural context of Japan, 3rd to 6th grade children aged between 8–12 years are categorised as elementary school students, whereas 7th to 9th grade adolescents aged 12–15 years are classified as junior high school students. We hypothesised that (1) experience of GRNP within the past one year would be higher in 7–9th grade youth footballers compared with those previously reported in 3rd to 6th grade children and that (2) body size (e.g., height and weight) and training volume (e.g., playing hours/days per week) in footballers aged 12–15 years would be linked to the prevalence of GRNP, a trend that is common to footballers aged 8–12 years in Japan.

2. Materials and Methods

2.1. Data Collection and Setting

The present study was a cross-sectional study based on data from children in 3rd to 6th grade; therefore, detailed survey items (screening and main questionnaires) have been described previously (Sasaki *et al*., 2023). Anonymous online questionnaires in a web-based survey (Rakuten Research, Inc., Japan) were used for data collection. Each parent of footballers in 7th to 9th grade answered information about their child, such as clinical characteristics (age, grade, weight, and height), sports-specific variables (dominant leg, playing position, and surface), weekly training volume (total days and hours football), and experience of GRNP (e.g., Osgood–Schlatter disease) within the past 1 year.

Detailed data setting for recruiting target participants is shown in Fig. 1. In the present study, the desired sample size (a total of 600 data, 200 footballers in each 7th to 9th grade) was achieved over three days (August 1–3, 2022). We confirmed the required sample size for *t* tests (d = 0.5, α level = 0.05, 1–β level = 0.95, allocation ratio = 5) and chi-square tests (w = 0.3, α level = 0.05, 1 − β level = 0.95, larger df = 7) by using prior power analyses. Finally, participants with GRNP and without injury were set at 126 and 389, respectively. This study was approved by the Ethics Committee of Tokyo Ariake University of Medical and Health Sciences (approval no. 0382).

2.2. Statistical Analysis

Descriptive statistics were expressed by continuous and categorical variables. Definitions of each category were based on a previous series of 3rd to 6th grade football players (Sasaki *et al*., 2023). Independent *t*-tests and chi-square tests were used to compare the difference between the two groups (with GRNP vs. without knee injury). Effect sizes for univariate analyses were calculated using Choen's d (<0.2, trivial; 0.21–0.5, small; 0.51–0.8, medium; and >0.8, large) and Cramer's V (<0.1, trivial; 0.11–0.3, small; 0.31–0.5, medium; and >0.5, large). Logistic regression analysis was also performed, and odds ratios (OR) and 95% confidence intervals (CI) were shown as the results. Variables with $p < 0.05$ in the univariate analysis (independent *t*-tests and chi-square tests) were entered into a multivariate model. Additionally, a receiver operating characteristic (ROC) curve was constructed to investigate the sensitivity and specificity of the variables used in the logistic regression model. Areas under the ROC curve and 95% CI were determined, and the optimal cut-off values were calculated. All statistical analyses were performed using SPSS Statistics version 22.0 for Windows.

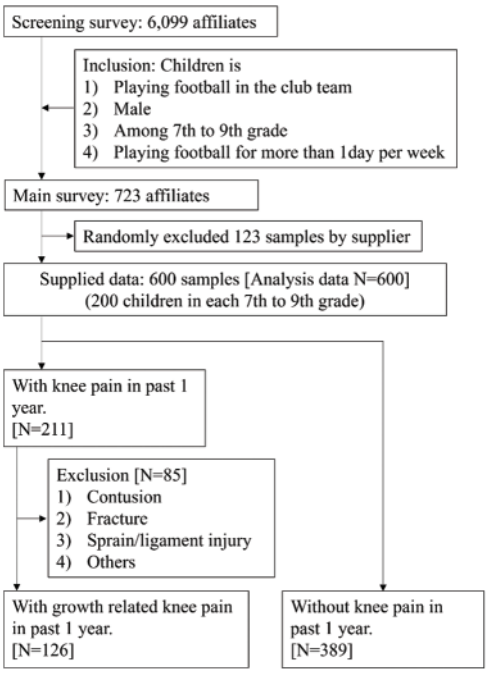

Fig. 1. Data setting.

3. Results

Experience of GRNP was observed in 21.0% (126 of 600 players aged 12–15 years; see Fig. 1). Table I shows the characteristics of youth footballers with and without GRNP within the recent 1 year. Players with GRNP had more training days ($p = 0.011$, d = 0.259) and hours ($p = 0.002$, d = 0.323) per week than those without knee pain. In contrast, clinical (age and body size) and sports-specific (dominant leg, position, surface) variables did not differ among the two groups.

TABLE I: Characteristics of Japanese Footballers (Aged 12–15 Years) with and without GRKP

	With GRNP (n = 126)	Without knee pain (n = 389)	p	ES
Age, mean ± SD, years	14.0 ± 0.8	13.8 ± 0.9	0.054	d = 0.203
Body height, mean ± SD, m	1.62 ± 0.08	1.60 ± 0.09	0.140	d = 0.160
Body height percentile cat. (%)			0.289	V = 0.110
<P3	1 (7.1)	13 (92.9)		
P3 to P10	4 (12.1)	29 (87.9)		
P10 to P50	55 (26.2)	155 (73.8)		
P50 to P90	53 (26.6)	146 (73.4)		
P90 to P97	9 (23.7)	29 (76.3)		
>=P97	4 (19.0)	17 (81.0)		
Body weight, mean ± SD, kg	48.6 ± 8.3	47.3 ± 8.6	0.146	d = 0.151
Body weight percentile cat. (%)			0.346	V = 0.104
<P3	0 (0.0)	5 (100.0)		
P3 to P10	7 (15.9)	37 (84.1)		
P10 to P50	44 (23.3)	145 (76.9)		
P50 to P90	61 (28.1)	156 (71.7)		
P90 to P97	9 (20.9)	34 (79.1)		
>=P97	5 (29.4)	12 (70.6)		
Body mass index, mean ± SD, kg/m^2	18.5 ± 2.5	18.3 ± 2.3	0.337	d = 0.097
Body mass index percentile cat. (%)			0.060	V = 0.162
<P3	3 (20.0)	12 (80.0)		
P3 to P10	4 (13.3)	26 (86.7)		
P10 to P25	21 (25.3)	62 (74.7)		
P25 to P50	27 (21.3)	100 (78.7)		
P50 to P75	43 (32.8)	88 (67.2)		
P75 to P90	12 (15.4)	66 (84.6)		
P90 to P97	10 (27.8)	26 (72.2)		
>=P97	6 (40.0)	9 (60.0)		

Tabel I (continued)

	With GRNP (n = 126)	Without knee pain (n = 389)	p	ES
Training days per week, mean ± SD, days	4.4 ± 1.5	4.0 ± 1.5	0.011	d = 0.259
Training hours per week, mean ± SD, hours	12.8 ± 6.2	10.8 ± 6.5	0.002	d = 0.323
Leg dominance, number (%)			0.073	V = 0.079
Right foot preferred	104 (23.2)	345 (76.8)		
Left foot preferred	22 (33.3)	44 (66.7)		
Position, number (%)			0.358	V = 0.040
Fielder	119 (24.9)	358 (75.1)		
Goalkeeper	7 (18.4)	31 (81.6)		
Training surface, number (%)			0.155	V = 0.085
Clay ground	105 (26.4)	292 (73.6)		
Artificial turf	18 (18.2)	81 (81.8)		
Natural grass	3 (15.8)	16 (84.2)		
Others	0 (–)	0 (–)		

Note. SD: standard deviation; Cat: category; ES: effect size; GRNP: growth-related knee pain.

Observing the logistic regression model, more weekly training hours (OR = 1.047; 95% CI, 1.016–1.079; $p = 0.003$) were significantly associated with the experience of GRNP (Table II). Weekly training days were excluded from the final logistic regression model due to the multicollinearity ($\rho = 0.645$, $p < 0.001$ for Spearman's rank correlation coefficient). The area under the ROC curve for training hours per week was 0.612 (95% CI, 0.555–0.669), and the optimal cut-off value was 12.5 h per week (sensitivity, 44.4%; specificity, 73.8%) for Japanese football players aged 12–15 years (see Fig. 2).

4. Discussion

The present study is a subsequent series of studies that examined the factors associated with GRNP in 3rd to 6th grade footballers (aged 8–12 years) (Sasaki *et al*., 2023). Among the 600 young Japanese

TABLE II: Logistic Regression Analysis of Japanese Footballers (Aged 12–15 Years) with GRKP

	Coefficient	OR	[95% CI]	p
Training hours per week	0.046	1.047	[1.016–1.079]	0.003
Constant	−1.668			

Note. OR: odds ratio; CI: confidence interval; GRNP: growth-related knee pain; model chi-square test ($p < 0.05$); overall percentage of correctly predicted: 75.0%; goodness-of-fit (Hosmer-Lemeshow statistic): 0.354.

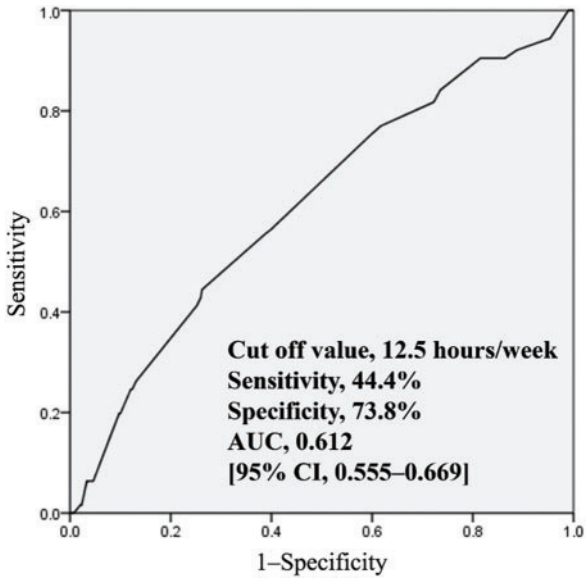

Fig. 2. Receiver operating characteristic curve for training hours per week. AUC: area under the curve; CI: confidence interval.

footballers in the 7–9th grade (aged 12–15 years), 21.0% (126 players) had experienced GRNP in the past 1 year. The prevalence of GRNP in the 7th to 9th grades was approximately two-fold higher than that in the 3rd to 6th grades (11.2%, as shown by Sasaki *et al*., 2023), which could prove our first hypothesis. Another study (Iwatsu *et al*., 2023) also investigated the point prevalence of knee pain among young Japanese players (7,234 participants from several sports) aged 6–15 years and showed that 13-year-old athletes had the highest rate of knee pain at 19.1%, which is similar to the present results. In an epidemiological study conducted in a Middle Eastern country (Qatar), the prevalence and occurrence rates of apophyseal knee injuries in young elite footballers aged 9–18 years were a median of 33.2% and 13.1 years old, respectively (Materne *et al*., 2022). In Qatar, the prevalence of apophyseal injuries in the knee joint was >30%, which was a surprisingly high proportion when compared with that in the present results; this may be due to the difference in study design, type of participants, and cultural context. Knee overuse problems, including apophysitis, lead to a great burden on both participation and performance in youth competitive football (Leppänen *et al*., 2019); therefore, coaches in the 13–14 years category should be aware of growth-related knee injury in order to prevent it.

Observing the clinical characteristics of young Japanese footballers aged 12–15 years, participants with knee pain did not differ in age and body size from those without painful episodes. Furthermore, sport-specific factors (dominant leg, position, and surface) were not associated with any episodes of GRNP among young Japanese football players. These results partially differ from those of our second hypothesis. According to a previous study series targeting 3rd to 6th grade children (Sasaki *et al*., 2023), age, height and weight were significantly associated with GRNP; however, this trend is not consistent with the present results for 7th to 9th grade children. A recent study by Murayama *et al*. (2023) showed that the actual age of peak height velocity (PHV) was 12.78 ± 0.93 years according to data of 207 Japanese boys observed over 12 years (2,484 observations), which is similar to the age of PHV at 12.61 years in Greek children (Kleanthous *et al*., 2022). Kleanthous *et al*. (2022) also observed that growth acceleration (take-off) began at the age of 9.86 years. Thus, 3rd to 6th grade Japanese children reported in a previous series (Sasaki *et al*., 2023) were just fit in the growth spurt for body size, while present youths in 7th to 9th grade are beginning to experience a decrease in body size velocity. Therefore, for youth footballers aged 12–15 years, chronological age or body size, such as height and weight, would not be principal risk factors for GRNP in Japan. Meanwhile, dominant leg, position, and surface did not affect the occurrence of GRNP throughout the 3rd to 9th grades (i.e., all footballers aged 9–15 years). Common views between previously reported children (3rd to 6th grade) and present youth (7th to 9th grade) footballers in Japan, the proportion of right-in-leg dominance (87.1% and 87.3%, respectively), playing as fielders (92.6% and 91.4%, respectively), and usually on the clay ground surface (77.0% and 77.1%, respectively) did not differ among school categories. In other words, circumstantial context may not affect the experience of GRNP in Japan.

Focusing on the training volume for youths in Japan, players with recent GRNP had significantly more weekly days and hours than those without knee pain. The training volume of 7th to 9th grade youth with knee pain was 1.5 days and 4.1 h on average, larger than those of 3rd to 6th grade children with knee pain shown in the previous report (Sasaki *et al*., 2023), which partly agreed with our second hypothesis. Additionally, when using the logistic regression model, more weekly training hours were identified as a significant risk factor for GRNP (OR = 1.047; 95% CI, 1.016–1.079). This means that for an increase of 1 h in training volume per week in Japanese footballers aged 12–15 years, the corresponding increase in the probability of GRNP within 12th month was 4.7%. Previous reports on footballers aged 8–12 years also showed a similar trend, in which more training hours per week (Sasaki *et al*., 2023) or training for >10 h per week (Iwame *et al*., 2019) were associated with a painful episode in the knee using logistic regression analysis. In youth sports, several recommendations regarding sports participation volumes have recently been made to prevent overuse injuries. One of these approaches is that young athletes should participate for fewer hours per week than their age or <16 h per week (LaPrade *et al*., 2016). In the present study, the cut-off value of training volume for footballers aged 12–15 years was 12.5 h per week using the present ROC analysis, which agrees with the recent guidelines shown by LaPrade *et al*. (2016). Jayanthi *et al*. (2015) also reported that injured young athletes (14.1 ± 2.1 years old, mean ± SD) significantly participated in more total hours of organised sports activities compared with uninjured athletes (11.2 vs. 9.1 h per week, on average). Additionally, current recommendations suggest that children who specialise in single sports activities should be closely monitored for indicators of burnout, overuse injury, or potential decrease in performance (LaPrade *et al*., 2016). A reason why increased sports participation volume in childhood is the sports specialisation, which is defined as year-round intensive training in a single sport with the exclusion of other sports (Jayanthi *et al*., 2013). In Japan, >75% of junior high school-aged footballers perform a single sport (football only); this proportion is much higher than that of elementary school-aged footballers at 43% (Nagano & Oyama, 2023a). Nagano and Oyama (2023a) also revealed that the appearance of overused knee injuries in junior high school was significantly associated with weekly sports participation, which was common in the present

study. Especially in Japan, specialised groups who continued a single specific sport in team sports had a greater prevalence of overuse injuries than a non-specialised group who previously participated in several sports, a trend that differed from that of individual sports (i.e., track and field and swimming; Nagano & Oyama, 2023b). Therefore, youth footballers categorised in team sports should control their training volume (combining adequate recovery) or introduce multisport events (other than football) to decrease the risk of overuse injuries, including growth-related pain.

Our study has several limitations. First, this was a cross-sectional study using a self-report questionnaire completed by parents, which might have included some bias. Second, a specific physician did not diagnose the knee symptom; therefore, GRNP in the present study may contain various conditions. However, we believe that a study series following 3rd to 6th grade football players focusing on GRNP is crucial. This challenge resulted in 1,800 Japanese children aged 8–15 years. Third, the outcome of the ROC curve analysis was not an excellent model (area under the curve, 0.612), with 44.4% sensitivity and 73.8% specificity. The present cut-off value of training volume (12.5 h per week) may be relatively suitable for detecting players without knee pain but not for detecting painful occasions.

5. Conclusions

The present study aimed to explore the factors associated with GRNP in Japanese footballers aged 12–15 years. Among junior high school footballers, 21.0% had experiences of GRNP in the past 1 year. More weekly training hours were significantly and positively associated with GRNP (OR, 1.047; 95% CI, 1.016–1.079). Additionally, the optimal cut-off value for training hours per week was 12.5 h, with low-to-moderate sensitivity (44.4%) and specificity (73.8%) when explored using ROC curve analysis (area under the curve, 0.612; 95% CI, 0.555–0.669). However, clinical (age and body size) and sport-specific (dominant leg, position, and surface) characteristics were not associated with any episode of GRNP. To decrease the risk of GRNP in young Japanese footballers, controlling the training volume, which combines adequate recovery or introducing multi-sports events, may be a key strategy for injury prevention.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

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