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Physical capacity, not skeletal maturity, distinguishes competitive levels in male Norwegian U14 soccer players

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The main aim of the present study was to compare skeletal maturity level and physical capacities between male Norwegian soccer players playing at elite, sub-elite and non-elite level. Secondary, we aimed to investigate the association between skeletal maturity level and physical capacities. One hundred and two U14 soccer players (12.8-14.5 years old) recruited from four local clubs, and a regional team were tested for bone age and physical capacities. Bone age was estimated with x-ray of their left hand and used to indicate maturation of the skeleton. Players went through a comprehensive test battery to assess their physical capacities. Between-groups analysis revealed no difference in chronological age, skeletal maturity level, leg strength, body weight, or stature. However, elite players were superior to sub-elite and non-elite players on important functional characteristics as intermittent-endurance capacity (running distance: 1664 m ± 367 vs 1197 m ± 338 vs 693 m ± 235) and running speed (fastest 10 m split time: 1.27 seconds ± 0.06 vs 1.33 seconds ± 0.10 vs 1.39 seconds ± 0.11), in addition to maximal oxygen uptake ($\dot{V}O_{2max}$), standing long jump, and upper body strength ($P < .05$ for all comparisons). Medium-to-large correlations were found between skeletal maturity level and peak force ($r = 695$, $P < .01$), power ($r = 684$, $P < .01$), sprint ($r = -.471$, $P<.001$), and jump performance ($r = .359$, $P < .01$), but no correlation with upper body strength, $\dot{V}O_{2max}$, or intermittent-endurance capacity. These findings imply that skeletal maturity level does not bias the selection of players, although well-developed physical capacity clearly distinguishes competitive levels. The superior physical performance of the highest-ranked players seems related to an appropriate training environment.

KEYWORDS
competitive levels, physical capacity, skeletal maturation, talent selection, youth soccer

1 | INTRODUCTION

Soccer is a multifactoral sport, where players are required to possess well-developed physical, psychological, technical, and tactical capacities. In youth soccer, players are selected to various teams and academies at an early age, with the main goal of further developing their skills and expertise. Entrance into elite academies, regional teams and national teams are regarded as important for promising players development.[1] Previous studies have indicated that superior physical performance influences the selection of players into youth academies,[2-4] suggesting that the best physical performers have an advantage compared with other players at the time of selection. Given the high physical demands of elite senior matchplay,[5,6] youth players indeed need a reasonably good level of both aerobic and anaerobic capacities.[7]

However, the selection of players often occurs during a period that coincides with the start of puberty and maturation toward adult state.[8,9] In most sports, the chronological age is used to define the different categories of competition. Still, the physical capacities of adolescence players within the same birthyear might be influenced by their biological maturation. In general, various indicators of maturity (eg, skeletal, somatic, and sexual) are well related; however, determination of bone age using x-ray has been proposed as the gold standard in youth athletes.[10] Chronological age correlates well with bone age before puberty, but during adolescence, bone age is more closely related to adult maturity levels, as bone age is related to timing of puberty and growth in stature of an individual.[11]

With bone age as a marker of maturity, studies have shown that more skeletally mature players have increased aerobic endurance, are faster and stronger compared with their less mature peers.[12,13] However, early maturing players may not necessarily maintain their advantage through the development process or have superior performance in adulthood.[14] Still, studies from Portuguese and Japanese soccer show that early maturers account for the highest percentage of players in elite youth teams,[15,16] which indicates a bias toward selecting the early maturing players.

Although there is growing evidence for the effect of maturation on physical performance in youth soccer, there is a need for large studies assessing maturity level during the talent selection process using the proposed gold standard of left hand x-rays. Previous samples of youth soccer players with inclusion of this method have mainly been investigated in French[17,18] and Portuguese populations[16,19] 15-20 years ago. No studies have been published from Norway or other Scandinavian countries, where coaches and teams could have a different approach in talent selection compared with South European countries. For instance the clubs in Norway are organized as voluntary associations, contrary to the professional organized clubs in South Europe.[20] While Norwegian clubs are not allowed to select players before the age of 13, due to restrictions from the Norwegian Soccer Federation ("Norges Fotballforbund"), many European clubs select players into academies already at an early age. To the best of our knowledge, the association between maturation and physical performance at the time when U14-players are selected to various competitive levels has not been extensively reported. As particularly the physical demands of elite senior soccer have increased rapidly in recent years, this could possibly affect recruiters and coaches to put more emphasis on fitness already at an early age.[5] In addition, previous studies have mainly focused on various aerobic endurance tests, vertical jump, and sprint tests, but few have included a comprehensive test battery assessing a wide array of physical capacities, both in a laboratory and field setting, required to reflect the complex physical demands of soccer.

It is essential to understand the role of maturity and physical performance in adolescence soccer, especially since this period coincides with selection of players to youth academies and elite teams. Therefore, the main aim of this study was to compare the level of skeletal maturity and physical capacities between players who were selected to play at elite level (national level), at sub-elite level (high local level), and at non-elite level (low local level). In addition, we aimed to investigate the association between skeletal maturity level and physical capacities. We hypothesize that players selected to play at elite level are at later stage of skeletal maturity and show superior physical performance compared with their lower level peers, and that there is an association between skeletal maturity and player physical capacity.

2 | MATERIALS AND METHODS

The current study is part of a longitudinal research project, examining factors related to talent development in youth soccer. Data in the present study are cross-sectional and represent the skeletal maturation and physical capacities of the players at the time of inclusion. Data were collected during a 3-week period in June 2018.

2.1 | Participants

In total, 102 male soccer players (age: 14.0 ± 0.3 years¸ height: 166.7 ± 8.2 cm, weight: 53.3 ± 9.6 kg,) from Western Norway participated. The players were recruited from various teams within four large local U14 clubs. We included teams that were competing at different competitive levels, and inclusion criteria were either that the teams played at national level, highest local level, and/or at the lowest local level. In addition, players from the elite regional team that were not playing for one of the four local clubs were included, to recruit all of the highest ranked players in the region. In our sample of players, 95 were born in 2004 and 7 in 2005. Of these, 26 players were selected to play matches for teams in the national U14-league in Norway (elite) and are recognized as some of the best players in Western Norway at this age. Further, 53 players were playing for teams at the highest local level (sub-elite) and 23 players for teams at the lowest local level (non-elite).

2.2 | Anthropometry and body composition

Anthropometric measurements included physical stature and body mass. Height was measured with a stadiometer (Seca 206 and Seca 217, Hamburg, Germany), recorded to the nearest cm. All measurements were performed barefoot using standard procedures. Body composition and body mass were estimated using an eight-polar bioimpedance method using multifrequency current (InBody™ 720, Biospace CO.). The specifications and technical information regarding the device have been reported previously.[21] Standard procedures were followed for all players.

2.3 | Questionnaire data

Data regarding player's chronological age, number of years playing organized soccer, number and hours of weekly organized soccer practices, and other organized physical training (endurance and strength training) were collected from a questionnaire that is part of a larger research project, assessing multiple variables regarding the player's background and youth development. The questions derived from the questionnaire were as follows: (1) "At what age did you start playing organized soccer?" (2) "During 2017, how many *times* a week did you participate in organized soccer practices, on average?" (3) "During 2017 how many *hours* a week did you participate in organized soccer practices, on average?" (4) "During 2017, how many *times* a week did you participate in other organized physical training, on average?" (5) "During 2017 how many *hours* a week did you participate in other organized physical training, on average?" (6) "So far in 2018, how many *times* a week have you participated in organized soccer practices, on average?" (7) "So far in 2018, how many hours a week have you participated in organized soccer training, on average?" (8) So far in 2018, how many *times* a week have you participated in other organized physical training, on average?" (9) So far in 2018, how many *hours* a week have you participated in other organized physical training, on average?" The data were collected after or prior to the physical testing session, depending on the player's testing schedule.

2.4 | Ethics

The Regional Committee for Medical and Health Research Ethics approved the study (2017/1731), which was conducted in accordance with the Helsinki declaration. Since players were under the legal age of consent, both the players and their parents gave a written informed consent for participation. All results were treated anonymously.

2.5 | Skeletal maturation expressed as bone age

All players underwent x-ray of their left wrist-hand in order to estimate biological and structural maturation based on their bone age. The x-ray images were obtained using Siemens Ysio Max with the integrated imaging system FLUORPSPO Compacts (software version VE10; Siemens Healthineers). The field of view covered the whole hand (posterior-anterior view), including 3 cm of the lower distal arm to include the epiphyseal plates in radius and ulna. The following acquisition parameters were used: tube-detector distance 1 m, x-ray energy 50-kilo volt (kV) and 1-1.5 milliampere-seconds (mAs), with no processing or filtering of the images.

The radiographs were analyzed using BoneXpert standalone version 2.5 (Visiana). The system automatically performs 8-13 independent bone age measurements from 8 to 13 different bones in the hand. The automated determination of bone age rules out inter- and intra-observer variation, and the bone age determinations are based on Greulich Pyle (GP) rating of bone maturation, as previously described.[22]

2.6 | Physical tests

Physical tests were performed during two different days for each player. On average, there were 6 ± 3 days between each of the two test days. Test day 1 included assessment of sprint, standing long jump, push-ups, brutal bench, and the Yo-Yo intermittent recovery level 1 test (IR1-test), whereas leg strength, countermovement jump (CMJ), and maximal oxygen uptake ($\dot{V}O_{2max}$) were tested on the second test day. The order of the tests within each test day was the same for all players. Each test was supervised and conducted by the same test personnel. All test personnel were highly trained with several years of experience conducting specific test, in various types of population. The players were wearing match suit or t-shirt, along with shorts and indoor sports shoes during the tests.

2.7 | 40-m linear sprint

The sprint tests were performed on an indoor track and timed with a wall-mounted photogate system (IC Control TrackTimer). The height of the first photogate was 50 cm above the running surface, whereas the photogates at 10, 20, 30, and 40 m were mounted 120 cm above the running surface.[23] A recent systematic review article states that linear-sprint tests covering distances up to 40 m possess validity and high intraday and interday reliability evaluating linear-sprinting skills in soccer players, with interclass correlation coefficients (ICC) ranging from 0.87 to 0.99 for comparable linear-sprint tests as in the present study.[24]

Before the sprint tests, all players performed a standardized 30-minute warm-up protocol led by a physical trainer. The protocol consisted of 10-minute low-intensity running, followed by 5 minutes of guided stretching (ie, of hamstrings, quadriceps, iliopsoas, and hip adductors). In the final part of warm-up, players performed 4 × 40-50 m linear runs with increasing intensity and speed, followed by two maximal linear accelerations of 20 m.

After the warm-up, all players performed three maximal sprints of 40 m separated by 2-3 minutes of rest. Players started in a standing position with split legs, with the toes of the front foot placed 60 cm behind the first photogates. The players started when ready without moving their body backward. The best (fastest) of three attempts was included in the analysis. Acceleration speed was defined as the time interval between 0-10 m and 0-20 m. Maximal speed was defined as the fastest 10 m split time.

2.8 | Jump performance

2.8.1 | Standing long jump

Players started with the toes of both feet placed behind a line and jumped as long as possible. Performance in standing long jump was determined by the jump distance, which was the horizontal distance from the take-off line to the mark made by the heel nearest the take-off line at the landing. To identify the landing mark, players had magnesium under the hind part of their shoes. The best of three attempts was used in the statistical analyses. A previous study shows that standing long jump is a highly reliable test (ICC = 0.99) of horizontal plane muscular power output, and that only three attempts, as we used in the current study, are necessary to establish a reliable maximal score.[25]

2.8.2 | Countermovement jump (CMJ)

The CMJ test was performed using a Kistler 9286B force plate (Kistler Instruments AG). From a standing position (with hands on hips and extended knee and hip), a countermovement jump was performed to a self-selected depth. Players were instructed to jump as fast as possible after descent and jump with straight legs in the air. Players received instructions on jump technique prior to jumping and were given the necessary trial jumps required to be familiarized with the jumping technique (in most cases only one jump). Maximum jump height (cm) was calculated using Kistler Measurement, Analysis and Reporting Software (MARS, 2015, S2P, Lubljana, Slovenia). The best of three attempts was used in the statistical analyses. Countermovement jump is commonly used in sports to measure explosive leg strength, and the use of a force plate is the gold standard. Countermovement jump height calculated from take-off velocity is a reliable measure, and ICC above 0.90 has been shown in different studies.[26]

2.9 | Hip, abdominal, and upper body strength

2.9.1 | Push-ups

Players started in plank position with hands shoulder-width apart (Figure 1). The players then bend their elbows until they touched the test leaders handheld in a flat position on the floor underneath their chest. Attempts that did not touch the test leaders hand were underruled. The spine had to be in a neutral position in each repetition, and the test lasted until

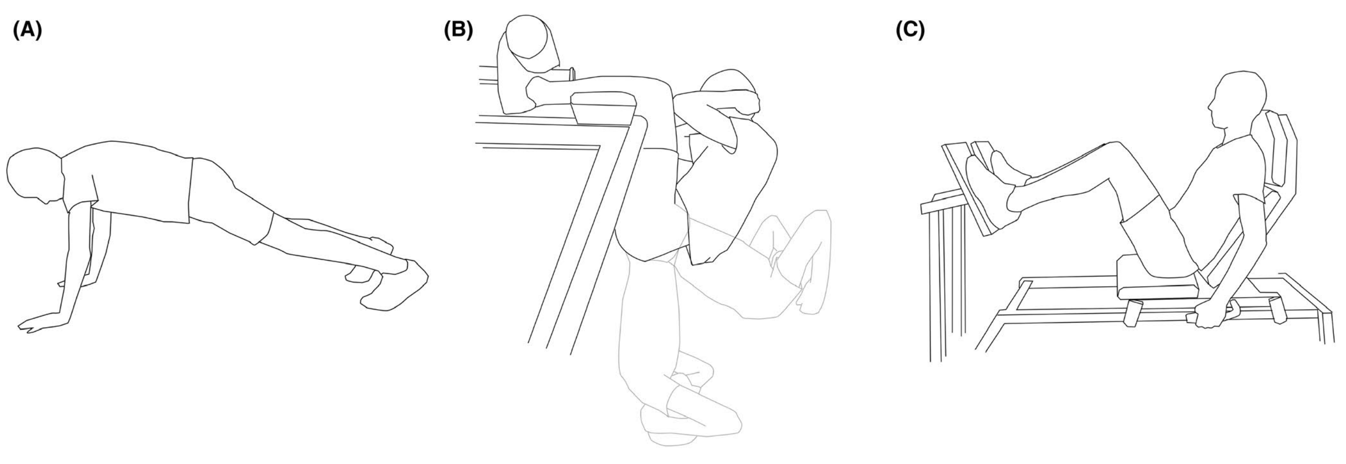

FIGURE 1 Strength assessments; (A) push-up, (B) brutal bench, and (C) leg strength and power

failure to complete a push-up. Maximum number of accepted repetitions was used in the statistical analyses.

2.9.2 | Brutal bench

The "brutal bench" is a vertical abdominal test that resembles a sit-up. Players started in a vertical position with the feet fastened in a 90-degree angle in the apparatuses, with their head closest to the floor and the hands of the players placed behind their head (Figure 1). To ensure that the hands stayed behind the head in the same position for all repetition, all players held on to a short string of rope tide in a circle. For each repetition, the elbows had to touch the knees. The maximum number of accepted repetitions was used in the statistical analyses.

2.9.3 | Leg strength and power

Leg strength was measured using the Keiser leg press (LP) machine (Keiser A300, Keiser Co. Inc) (Figure 1) and analyzed through the Keiser Air 420 software (version 9.3.42). Knee angle was measured with a goniometer and placed as close to 85 degrees as possible (84 ± 2.5°). For familiarization, all players performed two repetitions guided by experienced test personnel. A protocol consisting of 10 repetitions with increasing load and time between repetitions was used. The protocol is set by the Keiser software and determined by the players 1RM. Since the players had no previous experience with test, 1RM was based on visual observation of the players leg muscle mass from the test personnel. The test personnel had conducted over 200 tests at all athletic levels, and an investigation after the testing confirmed that the 1RM estimation was acceptable with an average of 10.3 ± 2.3 lifts for each player. From the 1RM estimate, the Keiser software calculated a 10-step protocol gradually increasing the resistance by equal percent intervals for each lift toward the estimated 1RM (Keiser A420 operations and maintenance manual). Players were instructed to do all repetitions with maximal effort. Peak power (Watt) and peak force (Newton) were used in the statistical analyses. A recent study using the Keiser leg press machine and the same protocol as in the present study shows that maximal strength and leg power output have an acceptable level of reliability in soccer players (ICC ranging from 0.87 to 0.91).[27]

2.10 | Aerobic capacity and intermittent-endurance capacity

Each participant performed 10-min warm-up on a treadmill prior to testing. The players ran at low intensity (increasing gradually from 8 to 10 km h^{-1}). Maximal oxygen consumption ($\dot{V}O_{2max}$) was determined during running at a constant inclination of 5.3% on a motorized treadmill (Woodway PPS$_{55}$, USA). This is a standardized test protocol used for soccer in Norway by the Norwegian Top Sport Centre ("Olympiatoppen"). The inclination of the treadmill limits the effect of running technique on test performance. The test protocol started with a speed between 7 and 10 km h^{-1}, where the test personnel made a subjective assessment of an appropriate starting speed for each participant. The test personnel were highly experienced and have conducted over 1000 $\dot{V}O_{2max}$ tests in all age groups and athletic levels. After the start of the test, speed was increased by 1 km h^{-1} every minute to voluntary exhaustion. $\dot{V}O_2$ was measured using a computerized metabolic system with mixing chamber (Oxycon Pro, Erich Jaeger GmbH). Prior to each test, the flowmeter was calibrated with a 3-L volume syringe (Hans Rudolph Inc), and the volume of oxygen (VO_2) and carbon dioxide (VCO_2) was calibrated using high-precision gases (16.00 ± 0.04% O_2 and 5.00 ± 0.1% CO_2, Riessner-Gase GmbH & co, Lichtenfels, Germany). $\dot{V}O_{2max}$ was defined as the highest average of two consecutive 30-second measurements.. Heart rate (HR) was measured with an HR monitor (Polar V800, Polar Electro OY). Within 30 seconds after completion of the test, players were asked to rate their perceived exertion using the Borg scale.[28]

The IR1 test was used to assess the players intermittent-endurance capacity. The test is a useful addition to a $\dot{V}O_{2max}$ test as it involves acceleration and deceleration and has shown to be highly correlated to match-related physical performance in youth soccer players, suggesting construct validity to match physical performance[29] with reliability (ICC ranging from 0.87 to 0.95) in adolescent soccer players.[30] The test was performed in an indoor gymnasium on a wooden sports floor, with a standardized starting speed for all players, in line with the procedures suggested previously.[31] The test was performed by the same test leader, with several years of experience in conducting Yo-Yo tests at different levels in soccer. Players had no previous experience with the IR1 test. Total distance covered was used for statistical analysis.

2.11 | Statistical analyses

Descriptive data are shown as mean ± standard deviation (SD). Visual inspection of histograms confirmed that the data were normally distributed. One-way ANOVA analyses were performed to evaluate group differences, and post-hoc tests were performed with Bonferroni correction. Relationships between variables were assessed using Pearson's correlation coefficient analysis. An *r*-value between .01 and .29 was defined as a small correlation, between 0.30 and 0.49 as a medium correlation, and from 0.05 to 1.0 as a large correlation (Cohen, 1988). All analyses were run with the maximum number of available participants in each case. Not all tests included the same number of participants, due to injuries/

TABLE 1 An overview of the physical capacities among all examined male soccer players with a mean age of 14.0 ± 0.3 y (n = 102)

	Mean ± SD	Min-max
Sprint (s)		
0-10 m	1.77 ± 0.10	1.58-2.13
0-20 m	3.22 ± 0.18	2.83-3.90
0-40 m	5.92 ± 0.38	5.11-7.41
Fastest 10 m	1.33 ± 0.10	1.13-1.74
Jump performance		
Standing long jump (m)	1.88 ± 0.23	1.25-2.58
Countermovement jump (cm)	28.7 ± 5.1	14.9-39.4
Maximal leg strength and power		
Power (W)	766 ± 195	430-1229
Force (N)	1580 ± 326	505-2536
Hip/abdominal/upper body strength		
Brtual bench (maximum reps)	11 ± 6	0-35
Push-ups (maximum reps)	26 ± 6	0-55
Endurance capacity		
$\dot{V}O_{2max}$ (mL kg^{-1} min^{-1})	60.5 ± 6.6	38.5-75.6
IR1-test (m)	1212 ± 448	200-2280

Abbreviations: CMJ, Countermovement jump; IR1-test, The Yo-Yo Intermittent Recovery test level 1; $\dot{V}O_{2max}$, maximal oxygen consumption.

sickness or missing attendance. However, after checking the possible influence of missing data on the descriptive data presented, close to identical values were found, and none of the statistical outcomes or conclusions were influenced. The Statistical Products of Service Solution package (SPSS Statistics, version 24) was used for all statistical analyses, and a *P*-value of .05 was considered as statistically significant.

3 | RESULTS

3.1 | Descriptive data for all participants

For all players, mean bone age was 13.9 ± 1.1 years, and percentage muscle mass and body fat were 49.9% ± 2.8% and 9.6% ± 4.7%, respectively. Descriptive statistics on players physical capacities are presented in Table 1.

3.2 | Physical capacities among players at different performance levels

One-way ANOVA analysis showed significant differences in speed, explosive leg strength, endurance capacity, and body fat and muscle mass percentage between players at various playing levels (Table 2). There were no significant differences in chronological age, bone age, body height, or body mass, nor in peak power or peak force obtained in the Keiser leg press machine between the groups.

Post hoc analyses showed that players at elite level were superior to players at sub-elite level in highest speed obtained over 10 m (P = .025), in standing long jump (P = .035), brutal bench (P < .001), push-ups (P = .024), Yo-Yo IR1 (P < .001), and in $\dot{V}O_{2max}$ (mL kg^{-1} min^{-1}) (P = .014).

Players at elite level also performed significantly better than non-elite players in sprint (0-10 m; P = .003, 0-20 m; P < .001, 0-40 m; P < .001, fastest 10 m; P < .001), standing long jump (P = .003), CMJ (P = .008), brutal bench (P < .001), push-ups (P < .001), IR1-test (P < .001), and $\dot{V}O_{2max}$ (mL kg^{-1} min^{-1}) (P < .001). In addition, elite level players had lower body fat (P = .017) and higher muscle mass percentage compared with non-elite players (P = .012).

Sub-elite players were superior to non-elite players in sprint (0-10 m; P = .015, 0-20 m; P = .021, 0-40 m; P = .013, fastest 10 m; P = .011), IR1-test (P < .001) and in $\dot{V}O_{2max}$ (mL kg^{-1} min^{-1}) (P = .009).

3.3 | Physical training among players at different performance levels

There was no difference between groups in age when starting with organized soccer training. However, players at elite level and sub-elite level reported significantly higher number and hours of weekly organized soccer training practice than non-elite players, both in 2017 (before selection) and in 2018 (from selection and until the physical testing) (Table 2). There was no significant difference between groups regarding other types of organized training activity (nor in numbers of weekly training sessions or training hours).

3.4 | Skeletal maturity level, chronological age, anthropometry, and physical capacities

Pearson's correlations analysis showed medium-to-large relationships between skeletal maturity level and chronological age (r = .320, P < .001), body height (r = .637, P < .001), body mass (r = .684, P < .001), and muscle mass percentage (r = .307, P < .001).

Large correlations were revealed between skeletal maturity level and peak power (r = .684, P < .001) and peak force (r = .695, P < .001) obtained in the Keiser leg press machine. Medium correlations were seen between skeletal maturity level and sprinting performance (r = −.416 to −0.471, P < .001, for all parameters), and between skeletal maturity level and jumping performance (standing long jump: r = .319, CMJ: r = .359, P < .001 for both).

There was no significant correlation between skeletal maturity level and body fat percentage, maximum repetitions in

TABLE 2 Physical capacity (mean ± SD) among youth male soccer players playing at different competetive levels

	Non-elite level† (n = 23)	Sub-elite level‡ (n = 53)	Elite level§ (n = 26)	*P*-values (main effect)	Post-hoc anlyses
Chronological age (y)	13.9 ± 0.2	13.9 ± 0.4	14.1 ± 0.3	.087	
Bone age (y)	13.9 ± 0.9	13.9 ± 1.1	14.0 ± 1.5	.943	
Age when started with organized soccer	5.4 ± 1.3	5.7 ± 1.2	5.5 ± 1.3	.633	
Weekly organized soccer practices in 2017					
Numbers	2.7 ± 0.8	4.1 ± 1.4	4.8 ± 1.3	<.001	§ > †, ‡ > †
Hours	3.1 ± 1.2	5.3 ± 2.5	6.7 ± 2.6	<.001	§ > †, ‡ > †
Weekly organized soccer practices in 2018					
Numbers	2.5 ± 0.8	4.8 ± 1.5	4.9 ± 1.2	<.001	§ > †, ‡ > †
Hours	3.3 ± 0.9	7.1 ± 2.6	8.4 ± 3.6	<.001	§ > †, ‡ > †
Height (cm)	166.3 ± 8.5	168.0 ± 7.2	164.3 ± 9.6	.164	
Body weight (kg)	56.4 ± 11.6	52.8 ± 7.8	51.7 ± 10.6	.213	
Body fat (%)	11.6 ± 7.2	9.8 ± 4.0	7.6 ± 2.6	.019	§ > †
Muscle mass (%)	48.7 ± 4.2	49.7 ± 2.5	51.1 ± 1.5	.012	§ > †
Sprint (s)					
0-10 m	1.83 ± 0.11	1.77 ± 0.09	1.74 ± 0.07	.002	§ > †, ‡ > †
0-20 m	3.33 ± 0.20	3.21 ± 0.17	3.14 ± 0.12	.001	§ > †, ‡ > †
0-40 m	6.17 ± 0.42	5.91 ± 0.37	5.73 ± 0.23	<.001	§ > †, ‡ > †
Fastest 10 m	1.39 ± 0.11	1.33 ± 0.10	1.27 ± 0.06	<.001	§ > ‡ > †
Jump performance					
Standing long jump (m)	1.79 ± 0.25	1.86 ± 0.22	1.99 ± 0.17	.004	§ > ‡, § > †
CMJ (cm)	26.0 ± 5.4	28.9 ± 4.8	30.5 ± 4.9	.010	§ > †
Maximal leg strength and power					
Peak power (W)	719 ± 134	759 ± 198	817 ± 224	.221	
Peak force (N)	1528 ± 224	1545 ± 336	1690 ± 361	.129	
Hip/abdominal/upper body strength					
Brutal bench (maximum reps)	9 ± 7	10 ± 5	16 ± 7	<.001	§ > ‡, § > †
Push-ups (maximum reps)	21 ± 10	26 ± 11	33 ± 10	.001	§ > ‡, § > †
Endurance					
$\dot{V}O_{2max}$ (mL kg^{-1} min^{-1})	55.6 ± 7.2	60.4 ± 5.9	64.5 ± 6.4	<.001	§ > ‡ > †
IR1-test (m)	693 ± 235	1197 ± 338	1664 ± 367	<.001	§ > ‡ > †

Note: One-way ANOVA was used to evaluate group differences, *P*-values represent main effects. Post hoc analyses are performed with Bonferroni corrections.
Abbreviations: $\dot{V}O_{2max}$ maximal oxygen consumption, IR1-test: The Yo-Yo Intermittent Recovery test level 1, CMJ: Countermovement jump.
†Elite.
‡Sub-elite group.
§Non-elite group.

brutal bench and push-ups, performance on the Yo-Yo IR1 test or in $\dot{V}O_{2max}$ (mL kg^{-1} min^{-1}).

3.5 | Self-reported training and physical capacities

Pearson's correlations analysis showed medium relationships between weekly number of organized training hours in 2018 and sprinting performance (r = −.392 to −.403, P < .001), jumping performance (standing long jump: r = .388, P < .001, CMJ: r = .351, P = .001), and maximal number of push-ups (r = .378, P < .001). Low correlations were revealed between number of weekly organized training hours in 2018 and performance in brutal bench (r = .257, P = .012), the Yo-Yo IR1 test (r = .226, P = .038), and peak force (r = .216, P = .041) and peak power (r = .253 P = .016) obtained in the Keiser leg press machine. There was no correlation between weekly number of organized training hours in 2018 and $\dot{V}O_{2max}$. The same pattern was seen for 2017, except for no correlation between weekly number of organized training hours and performance in brutal bench.

4 | DISCUSSION

In the present study, we compared skeletal maturity level and physical performance between U14 soccer players on three different competitive levels. In addition, the associations between skeletal maturity level and physical performance were examined. Our results showed that elite level players performed better on several measures of physical capacity compared with their lower level peers. However, there was no difference in skeletal maturity between the different competitive levels. Regardless, skeletal maturity level was positively associated with maximal leg strength and power, jump performance, and sprint performance, but not with aerobic capacity, intermittent-endurance capacity, push-ups, or hip flexor/abdominal strength.

This is the first study to show that the selection process of U14 players into elite versus non-elite groups is not affected by skeletal maturity level. Previous studies from Portuguese and Japanese soccer have shown that early maturing players account for a high percentage of players in elite youth teams.[15,16] The elite group in the present study could be recognized as some of the best players in Norway within their age group. As a reference, Norwegian national youth teams have in recent years qualified for European and World championships. Our findings indicate that skeletal maturity level does not discriminate between who can make it to the top youth level in Norway. This may relate to how Norwegian youth soccer is organized, with players selected at a later time than players in many of the professional academies in Southern European countries.[20] In addition, focus on the relative age effect (RAE)[32,33] may have led coaches and recruiters in Norwegian soccer to be more conscious about players stature and physicality in the selection process. Thus, we cannot exclude that the notion of RAE could have affected the selection of the present group of players.

The general assumption has been that maturation has biased the selection process during recruitment to the best teams, due to the association between skeletal maturity level, anthropometrics and physical fitness, and because physical performance has shown to influence talent identification for youth players.[3,12] Nevertheless, talent identification of the present group of players seems to fit well with the prospect of not predominantly selecting the early maturing players. Since previous research has identified that players who were successful in progressing to professional level upon graduation from academies were less mature compared with those who were unsuccessful,[17] this might be a beneficial strategy. Others have found that late matureres at the age of 14 were more likely to achieve success in adulthood, suggesting that early maturity does not coincide with higher level of performance at senior level, even though they have the potential to perform better physical at a younger age.[34] Hence, taking maturity level into account when selecting players to academies and teams could be a good approach, as this could level the playing field and give all players appropriate physical, psychological, tactical, and technical challenges that could optimize their development.

An important finding in the present study was that elite level players outperformed their lower level peers on several physical performance measures. In addition, the sub-elite players performed better than the non-elite players on several measures. This is in agreement with previous studies on U14 players that players selected to play at a higher level perform better on most physical measures compared with their lower level peers.[2,16] Specifically, our post hoc analyses showed that top speed, intermittent-endurance capacity, and aerobic capacity were progressively better for players as level of play increased. It is plausible that top speed is viewed as an essential physical skill already at an early age by coaches and recruiters. In the adult literature, speed has shown to be a highly important aspect of the game, with rapid increases in sprinting demands during recent years.[5] As sprinting often occurs during match-defining moments,[35] this indicates that the elite players have a potential advantage during significant moments of the game. Regardless, being quick even at a young age seems to be considered a pre-requisite to be selected for play at a higher youth level.

To the best of our knowledge, neither $\dot{V}O_{2max}$ or Yo-Yo IR1 has previously been compared between various performance levels in youth soccer. Yo-Yo IR1 has been validated in youth soccer to correlate well with match-related physical performance,[29] and although estimates of $\dot{V}O_{2max}$ have been reported,[18,36] none have objectively measured $\dot{V}O_{2max}$ using a computerized metabolic system with mixing chamber. A high aerobic capacity is an important functional capacity in soccer, as players with higher fitness could be in a better state to preserve the quality of soccer-specific skills for the duration of matches,[37] and recover more quickly between high-intensity bouts in order to execute a new technical or tactical action.[38] The superior intermittent-endurance capacity and aerobic capacity of the elite players could be explained by the tendency of a progressive increase in number of weekly organized soccer practices with increasing level of play, which also has been found in previous studies in youth soccer players.[39] In addition, the tendency of lower body fat and higher muscle mass in the elite players could come as a consequence of their training, and thus also be related to their superior physical fitness. It is plausible that players with less fat mass have an advantage in tasks requiring running over a prolonged period of time. Hence, our results indicate that lower level players might benefit from more training and increased fitness, which in turn could increase their chances of being selected to the top level. Regardless, since our data do not describe specific details on training, we cannot exclude that other factors (eg, better coaching, training content and intensity, and innate abilities) also could explain some of this advantage.

The significant correlations between skeletal maturity level and lower body force, power and sprint performance are in line with previous studies on U14 soccer players.[12,18] The significant medium correlation found between skeletal maturity level and higher muscle mass percentage substantiates the advantage more mature players have in actions requiring a high level of strength and power. The effect of maturation on physical performance could be expected, as increased skeletal muscle mass is generally a result of growth and maturation, which consequently alter absolute strength and contributes to the possible advantage in strength and power tasks.[8] On the other hand, we did not find any association between skeletal maturity level and aerobic capacity or intermittent-endurance performance. Although studies have previously shown that aerobic endurance is associated with maturity level,[12] our results could be explained by the significant large correlation between skeletal maturity and body mass. It could be expected that the higher body mass of the mature players presents a disadvantage during endurance running tasks, as more weight must be carried with each step. Hence, our findings indicate that being a more mature player within a team gives an advantage in soccer-specific actions requiring acceleration, speed, and jumping, but not necessarily the ability to sustain the length of a soccer match or training.

Overall, the abovementioned findings could possibly be explained by coaches and recruiters looking for players they view as fitted for the physical demanding requirements of modern soccer. It has recently been highlighted that physical performance measures on endurance, and sprint tests might have prognostic relevance for future success in adulthood,[4] indicating that these skills are an essential quality to possess during adolescence years. Our study also implies that superior physical performance can be achieved through high training volume during childhood and early adolescence. Indeed, the amount of accumulated high-level training has been shown to be a significant contributor to performance during an incremental shuttle run test in youth soccer players[12] and has also been found to be associated with selection into youth elite teams.[16] However, the reason for the superior performance of the elite group compared to the sub-elite is somewhat unclear and might be related to other factors than quantity of soccer-specific training.

5 | PERSPECTIVES

Selection of players into elite teams and academies during the time period of rapid growth and change in physicality may leave less matured players out, as a consequence of their biological development, rather than their future potential. However, the main findings of our study of Norwegian U14 players indicate that the selection of elite youth players is not biased by skeletal maturity level, although physical capacity clearly distinguishes different performance levels. While physical performance still seems to be an important aspect of the selection process, our results suggest that skeletal maturity is not the main reason for a superior physical fitness. In contrast, our data indicate that the superior physical performance of the highest ranked players could be related to an appropriate training environment, with a higher volume of soccer-specific training. This observation implies that players, independent of maturity level, who dedicatedly work to increase their physical capacity and soccer skills have a “fair chance” of making it into academies. Future research should seek to understand the relationship between training load, training quality, and development of physical capacity through childhood and adolescence, and explore the difference in training load when players are selected to various competitive levels.

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REFERENCES

1. Meylan C, Cronin J, Oliver J, Hughes M. Talent identification in soccer: the role of maturity status on physical, physiological and technical characteristics. *Int J Sports Sci Coaching*. 2010;5(4):571-592.
2. Vaeyens R, Malina RM, Janssens M, et al. A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *Br J Sports Med*. 2006;40(11):928-934.
3. Carling C, le Gall F, Reilly T, Williams AM. Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scand J Med Sci Sports*. 2009;19(1):3-9.
4. Murr D, Raabe J, Honer O. The prognostic value of physiological and physical characteristics in youth soccer: a systematic review. *Eur J Sport Sci*. 2018;18(1):62-74.
5. Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med*. 2014;35(13):1095-1100.
6. Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. High-intensity activity profiles of elite soccer players at different performance levels. *J Strength Cond Res*. 2010;24(9):2343-2351.
7. Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. *J Sports Sci*. 2000;18(9):669-683.

8. Malina RM, Bouchard C, Growth O-O. *Growth, maturation, and physical activity*. 2nd ed. Champaign, IL: Human Kinetics; 2004.
9. Ford P, Le Gall F, Carling C, Williams AM. A Cross-Cultural Comparison of the Participation Histories of English and French Elite Youth Soccer Players In: Reilly TaK F, ed. *Science and Football VI: The Proceedings of the Sixth World Congress on Science and Football.* Oxon: Routledge; 2009:138-142
10. Engebretsen L, Steffen K, Bahr R, et al. The International Olympic Committee Consensus statement on age determination in high-level young athletes. *Br J Sports Med*. 2010;44(7):476-484.
11. Roche AF. Bone Growth and Maturation. In: Falkner F, Tanner JM, eds. *Postnatal Growth Neurobiology*. Boston, MA: Springer US; 1986:25-60.
12. Malina RM, Eisenmann JC, Cumming SP, Ribeiro B, Aroso J. Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13–15 years. *Eur J Appl Physiol*. 2004;91(5–6):555-562.
13. Figueiredo AJ, Goncalves CE, Coelho E, Malina RM. Characteristics of youth soccer players who drop out, persist or move up. *J Sports Sci*. 2009;27(9):883-891.
14. Vaeyens R, Lenoir M, Williams AM, Philippaerts RM. Talent identification and development programmes in sport: current models and future directions. *Sports Med*. 2008;38(9):703-714.
15. Hirose N, Atsushi H. The bias toward biological maturation through the talent selection in Japanese elite youth soccer players. *Int J Sport Health Sci*. 2012;10:30-38.
16. Coelho E, Figueiredo AJ, Simoes F, et al. Discrimination of u-14 soccer players by level and position. *Int J Sports Med*. 2010;31(11):790-796.
17. le Gall F, Carling C, Williams M, Reilly T. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport*. 2010;13(1):90-95.
18. Carling C, Le Gall F, Malina RM. Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. *J Sports Sci*. 2012;30(15):1683-1693.
19. Malina RM, Pena Reyes ME, Eisenmann JC, Horta L, Rodrigues J, Miller R. Height, mass and skeletal maturity of elite Portuguese soccer players aged 11–16 years. *J Sports Sci*. 2000;18(9):685-693.
20. Gammelsæter H. The organization of professional football in Scandinavia. *Soccer Society*. 2009;10(3–4):305-323.
21. Sillanpaa E, Cheng S, Hakkinen K, et al. Body composition in 18- to 88-year-old adults–comparison of multifrequency bioimpedance and dual-energy X-ray absorptiometry. *Obesity (Silver Spring, Md)*. 2014;22(1):101-109.
22. Thodberg HH. Clinical review: An automated method for determination of bone age. *J Clin Endocrinol Metab*. 2009;94(7):2239-2244.
23. Haugen T, Buchheit M. Sprint running performance monitoring: methodological and practical considerations. *Sports Med*. 2016;46(5):641-656.
24. Altmann S, Ringhof S, Neumann R, Woll A, Rumpf MC. Validity and reliability of speed tests used in soccer: a systematic review. *PLoS ONE*. 2019;14(8):e0220982.
25. Reid C, Dolan M, DeBeliso M. The reliability of the standing long jump in NCAA track and field athletes. *Int J Sports Sci Coaching*. 2017;7(6):233-238.
26. Heishman AD, Daub BD, Miller RM, Freitas E, Frantz BA, Bemben MG. Countermovement jump reliability performed with and without an arm swing in NCAA division 1 intercollegiate basketball players. *J Strength Cond Res*. 2018;1-13
27. Redden J, Stokes K, Williams S. Establishing the reliability and limits of meaningful change of lower limb strength and power measures during seated leg press in elite soccer players. *J Sports Sci Med*. 2018;17(4):539-546.
28. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377-381.
29. Castagna C, Impellizzeri F, Cecchini E, Rampinini E, Alvarez JC. Effects of intermittent-endurance fitness on match performance in young male soccer players. *J Strength Cond Res*. 2009;23(7):1954-1959.
30. Deprez D, Fransen J, Lenoir M, Philippaerts R, Vaeyens R. The Yo-Yo intermittent recovery test level 1 is reliable in young high-level soccer players. *Biol Sport*. 2015;32(1):65-70.
31. Krustrup P, Mohr M, Amstrup T, et al. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc*. 2003;35(4):697-705.
32. Sæther SA. Selecting players for youth national teams – a question of birth month and reselection? *Sience Sports*. 2015;30:314-320.
33. Sæther SA. Presence of the relative age effect and its effect on playing time among under-20 players in the Norwegian premier league Tippeligaen – a four-year follow up. *J Sport SciMed*. 2016;5(1):11-15.
34. Ostojic SM, Castagna C, Calleja-González J, Jukic I, Idrizovic K, Stojanovic M. The biological age of 14-year-old boys and success in adult soccer: do early maturers predominate in the top-level game? *Res Sports Med*. 2014;22(4):398-407.
35. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci*. 2012;30(7):625-631.
36. Gil S, Ruiz F, Irazusta A, Gil J, Irazusta J. Selection of young soccer players in terms of anthropometric and physiological factors. *J Sports Med Phys Fitness*. 2007;47(1):25-32.
37. Rampinini E, Impellizzeri FM, Castagna C, Azzalin A, Ferrari Bravo D, Wisloff U. Effect of match-related fatigue on short-passing ability in young soccer players. *Med Sci Sports Exerc*. 2008;40(5):934-942.
38. Dupont G, McCall A, Prieur F, Millet GP, Berthoin S. Faster oxygen uptake kinetics during recovery is related to better repeated sprinting ability. *Eur J Appl Physiol*. 2010;110(3):627-634.
39. Rebelo A, Brito J, Maia J, et al. Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. *Int J Sports Med*. 2013;34(4):312-317.

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