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Original Article

Adolescent male soccer players have higher growth rates and risk of injury is associated with biological maturity

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ABSTRACT

Background. The objective of this study was to ascertain disparities in growth and maturation between male adolescents engaged in soccer and their non-athletic counterparts, as well as to examine the injury features specific to young soccer players.

Methods. A total of 206 soccer players between the ages of 11-16 years, and 208 non-athletic peers were enrolled. Height, weight, body mass index (BMI), annual growth rate, and skeletal age evaluated using a left hand-wrist x-ray were determined. Biological and sexual maturation were evaluated using skinfold thickness, body composition, and Tanner stages. The game positions, initial age for playing soccer, the number of games per/week, the number of sports injuries, date of injury, duration for return to activity, the site, nature, mechanism, and rate of injury were recorded for soccer players. Using an injury card, the characteristics of soccer player injuries were recorded.

Results. The mean age of the participants was 13.6 ± 1.5 years. There was no difference in the growth rates between the groups at the ages of 11.0, 12.0, and 15.0 but at the ages of 13.0 and 14.0 years growth rates were higher in the soccer group. The soccer players were taller than the controls. For all Tanner stages, soccer players had a lower BMI and total body fat percentage, as well as a faster growth rate. Injuries occurred at a rate of 39.3% per year among soccer players. The most common being toe injuries, and playing soccer increased the risk of multiple injuries. Additionally, injuries occurred more frequently in soccer players who were taller, heavier, with higher total body fat and/or higher growth rate, and most commonly occurred during Tanner stage 4. Futhermore, Tanner stage 4 had a higher incidence of two or more injuries than the other stages.

Conclusions. Adolescent male soccer players have higher growth rates than their non-athletic peers, and their biological maturity status is associated with an increased risk of injury.

Key words: maturity, tanner stage, soccer, injury, adolescence.

The achievement of physical growth, the development of secondary sexual characteristics and the maturation of psychosocial skills all occur during adolescence. This period of change and development is a vastly individual process, varying considerably.[1] Participating in sporting activities is also one of the factors that affects this variation among individuals. In the literature, an opposite relationship between physical activity and the timing of biological maturation has been reported.[1] Although some studies have shown that male adolescents with insufficient physical activity have an earlier risk of maturation[2], it has similarly been reported that those adolescents who engage in vigorous physical activity may also mature earlier than

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their peers.[3] Regular physical training and participation in sports have not been shown to have an impact on the timing, grade or size of the growth spurt in many studies.[4,5]

In the first decade of the new millennium, the age of participation in sports has decreased, whereas the intensity of training has increased, which in turn is associated with an increase in acute and overuse injuries.[6] An important topic when discussing participation in sports during childhood and adolescence is the injury of the developing musculoskeletal system, especially the epiphyseal or growth plate.[7] Epiphyseal injuries can disrupt normal bone development and growth causing permanent damage. It has been reported that the incidence of injury is high during the growth spurt period because of non-linearity and the complexity of growth with a period of clumsiness in motor coordination, in addition to changes in flexibility and increase in stiffness when growth accelerates and maturation increases.[8-10] Decreased flexibility causes acute or overuse injuries, especially in boys and body mass index (BMI), fat percentage, and muscle mass changes are also reported as anthropometric factors that have an influence on injury risk.[8] On the other hand, no significant relationship between early and late maturation and injury risk has been reported in some studies.[11,12] In adolescent male soccer players, injury range has been reported from 38 to 85%, with 0.4-2.2 injuries per player per season.[13] Soccer is the most popular team sport in Turkey and children start playing at an early age. A large group of young players attend local youth soccer clubs affiliated with professional soccer clubs. In a study investigating the admissions to a sports medicine outpatient clinic in our country, it was reported that injuries in children and adolescents occurred at a rate of 23.3% in soccer, 17.2% in basketball and 14.5% in volleyball.[14]

In the literature, epidemiological studies on soccer injuries among adolescents have been conducted primarily in European settings, resulting in a geographic imbalance.[13] Although in recent years a great deal of focus has been placed on the injury risk of adolescent soccer players in order to reduce medical health care costs, promote talent development, and introduce an adequate prevention program, some areas, such as evaluating biological maturity, are still lacking.[15]

This study aimed to assess the growth, skeletal, and sexual maturation of male soccer players and non-athletic peers, as well as the injury characteristics of the soccer players. To the best of our knowledge, this is the first study evaluating this in Turkey. We hypothesize that biological maturation will influence injury rate, particularly as growth accelerates.

Materials and Methods

This was a prospective, cross-sectional study. It was approved by the institutional review board. Informed consent was obtained from all the participants and their parents or guardians. Male adolescent soccer players from the infrastructure of two Turkish Super League clubs, two from Istanbul and two from Ankara, comprised the study group. The training frequency was usually five days a week, one game day/week (Saturday), one day off/week (Sunday), and an average of 90 minutes a day, including warm-up, cooling, endurance, strength, speed, technical, tactical training, and game form. The control group included male adolescent volunteers who did not regularly participate in any sports with no chronic disease, did not take any medication and volunteered to participate in the study. The initial study group comprised 550 male soccer players and 393 controls. Those with missing data, including a left wrist radiograph, were excluded. Finally, 206 soccer players and 208 healthy controls, between the ages of 11-16, were included in the study. All the analyses were performed between January 2017 and September 2018. Growth rate, biological maturation (somatic assessment), and sexual and skeletal maturation were assessed in both groups. Additionally, for the soccer players, the game positions, initial age for playing soccer, number of games per week, number of sports injuries, date of injury, duration for return to activity, site of injury, injury type, and mechanism of injury were recorded, and injury rate was calculated.

Growth rate: The participants and their parents were asked for their height assessment from last year to establish one-year linear growth and established growth rate (cm/year). Current height, was measured using a stadiometer, all participants were weighed using TANITA 418 (Tanita, Japan) with an error of 0.1kg and BMI was calculated (weight (kg)/height (m^2).

Body Compositions: The skinfold thickness measurements of five areas (triceps, subscapular, abdominal, thigh, and calf) were performed using the Holtain caliper following the standard procedure. Body composition in terms of total body fat, water, and fat-free mass (FFM) was measured using a TANITA 418.

Standard deviation scores (SDS) of all measurements according to Turkish standards were calculated.[16]

Skeletal maturation: A left-hand wrist radiograph was obtained. Skeletal age assessment was performed independently by the same physician using the Greulich-Pyle method.

Sexual maturation: Sexual maturation status was evaluated by showing the participants the Tanner Pubertal Stages Form and using it as a self-assessment tool by the same physician. This method has been shown to be reliable for determining pubertal staging when the examination is not possible.[17]

All data were collected between 06:00-08:00 am prospectively after 12 hours of overnight fasting. The participants were evaluated as barefoot and wearing only shorts. The Endocrine Calculator (ENDO-C) and CHILD Metrics computer programs were used to establish the parameters.

Injury: The Elite Clubs Injury Form[18] was used to assess sports injuries. All injuries, as well as the time spent in games and/or regular activities and the need for medical care were assessed. Details concerning the injuries were asked of the parents, participants, and if possible, their physicians. The details of injuries such as mechanism (dribbling, collision, or other mechanisms) and injury type (fractures, strains, and sprains.. .etc) were asked. The injury incidence was calculated as injuries per 1000 hours of exposure (training and games).

Statistical analysis

IBM SPSS for Windows Version 22.0 package program was used. The results were presented as mean +/- SD for normally distributed variables; and as median (IQR) or median (Q1-Q3) for non-normally distributed variables throughout the main document and tables. The methods applied were frequencies, cross-tabulations, descriptive statistics, and means were calculated. When parametric test assumptions were provided, the Mann-Whitney U test was used when the Student’s t-test was not provided, and the comparison of numerical variables between more than two groups was investigated using one-way ANOVA or Kruskal-Wallis test. Pearson correlation coefficients were calculated for correlation analyses. Logistic regression analysis was performed for injury risk analysis. Differences between groups were examined using the chi-square test. The level of significance was set at 5%.

Results

Participants were aged 13.6±1.5 years. The skeletal age was 13.7±1.6 years in the study group and 14.3±1.6 years in the control group. Age, anthropometry, and body composition characteristics are shown in Table I.

There was no difference in the growth rates (cm/year) between the groups at the ages of 11.0, 12.0, and 15.0 (p>0.05) but at the age of 13.0 years [(7.7±3.3 cm/year in the study group vs 3.9±2.4cm/year in controls and p=0.033, respectively)] and 14.0 years [(7.8±3.3 cm/year in the study group vs. 5.5±2.9 cm/year in controls and p=0.028)] growth rates were higher in the study group. At the age of 16 years, it was

Table I. Demographic features of participants.

	Study Group		Control Group		Total		
	N	Median (min-max)/ Mean±SD	N	Median (min-max)/ Mean±SD	N	Median (min-max)/ Mean±SD	p
Age	206	13.4±1.5	208	13.8±1.5	414	13.6±1.5	0.019[t]
Skeletal age	206	13.7±1.6	208	14.3±1.6	414	14.0±1.8	<0.001[t]
Height (cm)	204	168.5 (130.0-190.0)	205	165.0 (132.0-185.0)	409	166.0 (130.0-190.0)	<0.001[m]
Height (p)	204	64.9±25.7	205	41.3±28.3	409	53.1±29.5	<0.001[t]
Weight (kg)	206	53.0±12.3	207	56.3±12.8	413	54.6±12.7	0.008[t]
Weight (p)	206	38.2 (1.0-95.3)	207	39.3 (1.0-99.5)	413	38.9 (1.0-99.5)	0.748[m]
BMI (kg/m^2)	204	18.7 (13.4-25.0)	204	20.6 (13.8-33.6)	408	19.6 (13.4-33.6)	<0.001[m]
BMI (p)	204	29.1 (1.0-82.6)	204	44.5 (3.0-99.5)	408	34.0 (1.010.0-99.5)	<0.001[m]
Growth rate (cm/y)	117	5.0 (0.0-19.0)	112	5.0 (0.0-18.0)	229	5.0 (0.0-19.0)	0.424[m]
Growth rate SDS	116	(-0.1)±1.7	112	0.0±1.4	228	0.0±1.6	0.266[t]
Total body fat%	206	12.9 (5.9-21.9)	208	17.2 (9.0-38.9)	414	14.9 (5.9-38.9)	<0.001[m]
Total body water%	193	43.5 (17.1-66.8)	208	33.4 (10.3-53.4)	401	36.7 (10.3-66.8)	<0.001[m]
FFM%	193	59.4 (23.3-91.1)	208	45.6 (10.9-74.4)	401	50.1 (10.9-91.1)	<0.001[m]
Abdominal fat%	206	8.7 (3.0-18.4)	208	13.4 (4.4-33.7)	414	10.9 (3.0-33.7)	<0.001[m]
Triceps (mm)	206	14.1 (5.0-28.0)	207	12.3 (5.0-26.8)	413	13.0 (5.0-28.0)	0.001[m]
Subscapular (mm)	206	12.3±4.5	208	11.3±4.5	414	11.8±4.5	0.024[t]
Abdominal (mm)	206	12.0 (4.04.0-27.0)	208	13.8 (5.0-37.0)	414	13.0 (4.0-37.0)	0.001[m]
Thigh (mm)	206	17.2 (8.4-34.0)	208	13.0 (7.0-28.0)	414	15.0 (7.0-34.0)	<0.001[m]
Calf (mm)	206	14.8 (6.0-33.3)	208	11.4 (5.2-24.6)	414	13.0 (5.2-33.0)	<0.001[m]

BMI: body mass index, FFM: fat-free mass, m: Mann Whitney U test, Mean±SD: mean±standart deviation, p: percentile, SDS: standart deviation score, t=Student t test, [(Measurements that are not noted, are considered as the number of missing data (height (cm) 204, height (p) 204, BMI (kg/m^2) 204, BMI (p) 204, Growth rate (cm/y) 117, Growth rate SDS 116, Total body water% 193, FFM% 193)].

[(2.9±1.6 cm/year in the study group vs. 6.4±3.0 cm/year in controls and (p=0.004)] higher in the controls.

The triceps and subscapular skinfold thicknesses were lower at the ages of 11.0, 12.0, and 13.0 years in the study group when compared to the controls, but at the ages of 14.0, 15.0, 16.0 years they were thicker than the controls. The parameters were compared according to chronological age and are presented in Table II.

The growth rate was evaluated according to the Tanner stage, and although there was no difference, it was found to be higher in the study group for Tanner stage 1-4 (p>0.05), but it was higher in the control group at stage_5 (p=0.012). A comparison of all the parameters according to the Tanner stages is presented in Table III.

In the study group, 8.7% were goalkeepers, 35.9% were defenders, 37.4% were strikers, and 37.4% were midfield players. The initial age for playing soccer was 8.3±1.9 years and the number of games played in the previous season was 23.6±9.4. The amount of time spent with training was 4.7±0.4 days/week and 82.5±13.4 min/day. There were no differences between playing positions and total body fat (p=0.098), FFM (p=0.580), or total body water (p=0.578). Training time (hours/day) had a negative correlation with total body fat (rho= -0.443, p<0.001), total abdominal fat (rho= -0.528, p<0.001), and abdominal skinfold thickness (rho= -0.434, p<0.001), and positively correlated with total body water (rho= 0.749, p<0.001) and FFM (rho= 0.750, p<0.001). A positive correlation was found between the growth rate and hours of training (rho= 0.379, p<0.001), and no correlation was observed with the training time (day) (rho= 0.178, p=0.055).

Table II. The comparison of growth and body parameters according to chronological age.

Age	Group		Skeletal Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Growth rate (cm/year)	FFM%	Total Body water%	Total body fat%	Abdominal fat%	Triceps caliper (mm)	Subscapular caliper (mm)	Abdominal caliper (mm)
11	Study	N	25	25	25	25	21	25	25	25	25	25	25	25
		Median(min-max)/ Mean±SD	12.0 (11.0-12.0)	151.5 (130.0-175.0)	38.0 (27.0-50.0)	17.2±1.6	4.0 (0.0-19.0)	36.6 (23.3-89.3)	26.8 (17.1-65.3)	14.4±2.7	9.5±2.9	12.9 (6.0-24.4)	9.9±3.1	14.3 (6.0-25.8)
	Control	N	22	22	22	22	8	22	22	22	22	22	22	22
		Median(min-max)/ Mean±SD	12.0 (10.0-13.0)	145.5 (132.0-161.0)	43.0 (29.0-71.0)	20.6±4.3	5.0 (3.0-8.0)	33.0 (24.9-44.1)	24.1 (18.2-32.3)	23.5±7.6	19.1±7.7	16.0 (7.3-23.0)	13.4±5.7	17.9 (7.1-35.6)
		p	0.865m	0.064^{m}	0.162^{m}	**0.005**	0.79^{m}	0.065^{m}	0.062^{m}	**<0.001**	**<0.001**	0.381^{m}	**0.035**	0.094^{m}
12	Study	N	36	36	36	36	18	36	36	36	36	36	36	36
		Median(min-max)/ Mean±SD	12.2±0.8	156.0 (146.0-175.0)	41.5±6.2	16.8±1.7	5.0 (0.0-10.0)	68.9±24.8	50.4±18.1	13.0±3.0	8.2±3.3	11.5±4.0	9.0±2.7	12.9±5.3
	Control	N	25	25	25	25	7	25	25	25	25	25	25	25
		Median(min-max)/ Mean±SD	12.7±0.6	153.0 (146.0-172.0)	48.4±9.6	20.3±3.7	6.0 (2.0-8.0)	37.7±6.0	27.6±4.4	21.2±5.9	16.8±6.5	15.2±4.8	11.3±4.5	16.6±6.0
		p	**0.023**	0.143^{m}	**0.004**	**<0.001**	0.363^{m}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.002**	**0.035**	**0.015**
13	Study	N	41	39	41	39	22	41	41	41	41	41	41	41
		Median(min-max)/ Mean±SD	13.0 (12.0-15.0)	163.0 (150.0-180.0)	48.0 (34.0-68.0)	18.2±1.9	7.7±3.3	63.3±23.2	46.3±17.0	12.6±2.1	8.2±2.4	12.0 (7.0-26.0)	10.0 (5.0-24.0)	12.4±4.0
	Control	N	24	23	24	23	10	24	24	24	24	24	24	24
		Median(min-max)/ Mean±SD	13.0 (12.0-14.0)	162.0 (147.0-174.0)	51.5 (33.0-82.0)	20.2±3.6	3.9±2.4	42.0±7.7	30.8±5.6	18.1±5.3	14.1±4.9	12.8 (8.5-26.8)	10.3 (5.6-25.2)	15.1±6.2
		p	0.083^{m}	0.06^{m}	0.175^{m}	0.033	**0.003**	**0.001**	**0.001**	**<0.001**	**<0.001**	0.743^{m}	0.971^{m}	**0.038**
14	Study	N	47	47	47	47	26	44	44	47	47	47	47	47
		Median(min-max)/ Mean±SD	14.0±0.8	173.6±6.2	58.9±7.7	19.3 (16.4-23.8)	7.8±3.3	68.8±18.9	50.4±13.8	12.6±2.0	8.4±2.4	17.9±5.3	14.4±4.2	11.0 (4.0-22.5)
	Control	N	63	61	63	61	37	63	63	63	63	62	63	63
		Median(min-max)/ Mean±SD	14.4±0.8	166.0±7.0	58.6±13.3	20.5 (14.4-33.6)	5.5±2.9	47.5±8.5	34.5±5.7	18.6±6.1	14.9±6.6	12.9±4.3	11.3±4.8	13.0 (5.0-37.0)
		p	**0.009**	**<0.001**	**<0.001**	0.396^{m}	**0.028**	**0.005**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.001**	0.062^{m}
15	Study	N	36	36	36	36	18	29	29	36	36	36	36	36
		Median(min-max)/ Mean±SD	14.9±0.8	175.6±6.8	62.0 (30.0-80.0)	20.5 (15.3-25.0)	8.5 (2.0-13.0)	68.6±19.4	50.2±14.2	13.8±2.9	10.3±3.2	14.0±3.8	12.4±3.1	12.0 (6.0-21.6)
	Control	N	46	46	45	45	35	46	46	46	46	46	46	46
		Median(min-max)/ Mean±SD	15.3±0.9	168.7±5.9	59.0 (46.0-80.0)	20.4 (17.1-29.4)	6.0 (0.0-18.0)	50.6±6.8	37.1±5.0	17.4±4.5	13.9±4.8	11.8±3.9	10.5±4.1	13.0 (5.0-36.1)
		p	**0.016**	**<0.001**	0.449^{m}	0.177^{m}	0.698^{m}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.017**	**0.024**	0.623^{m}
16	Study	N	21	21	21	21	12	18	18	21	21	21	21	21
		Median(min-max)/ Mean±SD	17.0 (15.0-18.0)	176.8±6.9	70.0 (51.0-81.0)	21.4 (18.2-24.9)	2.9±1.6	57.3±6.3	42.1±4.2	15.7 (12.2-21.4)	12.5 (8.4-18.1)	21.0±3.6	18.6±3.2	13.0 (8.0-19.0)
	Control	N	28	28	28	28	15	28	28	28	28	28	28	28
		Median(min-max)/ Mean±SD	17.0 (14.0-17.0)	169.5±7.4	60.0 (42.0-87.0)	21.4 (17.0-30.5)	6.4±3.0	51.2±10.6	37.6±7.4	15.6 (10.7-22.7)	12.6 (7.5-19.4)	11.8±3.7	11.3±3.1	14.4 (7.8-30.1)
		p	0.223^{m}	**0.001**	0.121^{m}	0.832^{m}	**0.004**	**0.035**	**0.024**	0.686^{m}	0.976^{m}	**<0.001**	**<0.001**	0.107^{m}

BMI: body mass index, FFM: fat-free mass, m: Mann Whitney U test, Mean±SD: mean±standart deviation, p: percentile, SDS: standart deviation score, t: Student t test.

Table III. The comparison of growth and body parameters according to chronological age.

Tanner Stages	Group		Height (cm)	Weight (kg)	BMI (kg/m²)	Growth rate(cm/year)	FFM%	Total body water %	Total body fat %	Abdominal fat %	Triceps calliper (mm)	Subscapular calliper (mm)	Abdominal calliper (mm)
1	Study	N	9	9	9	7	9	9	9	9	9	9	9
		Median(min-max)/ Mean±SD	148.5±5.9	39.0±6.1	17.6±2.1	5.2±2.2	32.5±4.2	23.8±3.0	14.6 (5.9-19.9)	9.8 (6.3-15.0)	16.9±3.6	11.5±3.2	18.4±5.1
	Control	N	16	16	16	7	16	16	16	16	16	16	16
		Median(min-max)/ Mean±SD	144.0±6.3	41.6±9.2	19.9±3.6	4.4±1.9	31.9±5.1	23.3±3.7	22.7 (12.5-30.5)	17.2 (6.7-28.1)	14.5±3.9	12.4±5.1	17.1±6.7
		p	0.091*	0.454*	0.101*	0.469*	0.751*	0.748*	0.015 KW	**0.008** KW	0.149*	0.621*	0.613*
2	Study	N	47	49	47	28	49	49	49	49	49	49	49
		Median(min-max)/ Mean±SD	156.2±8.5	40.0 (27.0-68.0)	17.4 (13.8-21.5)	4.9±4.5	45.4 (23.3-90.3)	33.3 (17.1-66.1)	12.9 (9.4-21.9)	8.5 (3.5-18.4)	11.5 (6.0-24.4)	9.0 (5.0-18.1)	13.0 (6.0-27.0)
	Control	N	27	29	27	12	29	29	29	29	29	29	29
		Median(min-max)/ Mean±SD	154.8±6.6	49.5 (32.0-71.0)	20.5 (14.1-30.7)	5.0±2.2	37.1 (26.5-48.7)	27.2 (19.4-35.7)	19.2 (12.1-38.9)	14.6 (7.5-33.7)	15.0 (7.6-25.1)	11.3 (3.2-23.2)	17.0 (6.8-35.6)
		p	0.462*	**0.004** KW	**<0.001** KW	0.912*	**<0.001** KW	**<0.001** KW	**<0.001** KW	**<0.001** KW	**0.002** KW	**0.001** KW	**0.021** KW
3	Study	N	53	53	53	32	51	51	53	53	53	53	53
		Median(min-max)/ Mean±SD	165.3±9.9	53.0 (30.0-76.0)	18.0±2.3	7.3±3.1	58.9 (26.0-91.1)	43.2 (19.0-66.8)	12.5 (8.9-18.5)	8.1 (3.0-15.1)	14.3±5.6	11.9±4.8	12.0±3.9
	Control	N	58	58	58	32	58	58	58	58	57	58	58
		Median(min-max)/ Mean±SD	163.5±9.5	53.0 (33.0-96.0)	20.2±3.9	5.7±3.4	44.4 (27.8-74.4)	32.5 (20.4-48.8)	15.9 (10.2-34.3)	12.1 (6.4-32.8)	12.2±3.7	10.3±4.3	13.6±6.6
		p	0.317*	**0.049** KW	0.101*	0.052*	**<0.001** KW	**<0.001** KW	**<0.001** KW	**<0.001** KW	0.094*	0.071*	0.408*
4	Study	N	75	75	75	43	67	67	75	75	75	75	75
		Median(min-max)/ Mean±SD	174.0 (153.0-190.0)	59.7±7.9	19.7 (15.6-24.9)	7.3±3.2	85.5 (39.1-90.7)	62.6 (28.6-66.4)	12.8 (9.0-21.4)	8.4 (3.4-18.1)	15.6 (7.0-28.0)	12.7 (7.0-26.0)	11.0 (4.0-22.5)
	Control	N	75	75	74	50	76	76	76	76	76	76	76
		Median(min-max)/ Mean±SD	168.0 (155.0-185.0)	61.6±10.9	21.2 (16.6-32.0)	6.7±3.0	50.3 (10.9-72.9)	36.8 (10.3-53.4)	16.7 (9.0-32.7)	13.4 (4.4-28.4)	11.6 (5.0-25.0)	10.0 (5.0-26.3)	13.2 (5.0-36.1)
		p	**<0.001** KW	0.374*	**<0.001** KW	0.385*	**<0.001** KW	**<0.001** KW	**<0.001** KW	**<0.001** KW	**<0.001** KW	**<0.001** KW	**0.021** KW
5	Study	N	20	20	20	7	17	17	20	20	20	20	20
		Median(min-max)/ Mean±SD	178.0 (164.0-190.0)	70.0 (51.0-81.0)	21.9±1.4	2.0 (1.0-3.0)	59.1 (41.8-89.6)	43.3 (33.6-65.6)	15.7±2.7	12.0±3.2	21.0 (10.8-27.0)	17.5 (11.0-22.0)	12.9±3.0
	Control	N	10	10	10	6	10	10	10	10	10	10	10
		Median(min-max)/ Mean±SD	169.5 (155.0-175.0)	59.0 (53.0-80.0)	21.9±3.3	3.5 (2.0-4.0)	49.2 (44.8-61.8)	36.1 (32.8-45.2)	16.7±3.8	13.7±3.7	10.5 (5.1-22.3)	9.6 (7.0-20.0)	14.5±4.8
		p	**<0.001** KW	**0.038** KW	0.553*	**0.012** KW	**0.011** KW	**0.008** KW	0.418*	0.203*	**0.001** KW	**0.001** KW	0.266*

BMI: Body mass index, FFM: fat-free mass, KW=Kruskall Wallis, Mean±SD: mean±standart deviation, p: percentile, SDS: standart deviation score, *=One way ANOVA.

Injury

The injury rate in soccer players was 39.3% per year, and playing soccer increased the risk of multiple injuries [(OR=0.084, CI 0.018-0.384, p=0.002)]. There was a difference between Tanner stages comparing rates of injury (p<0.05), as the injuries were most common in Tanner stage 4 (16.0%) [(1.5% stage 1, 6.3% stage 2, 9.2% stage 3, and 6.3% stage 5)]. Additionally, two or more injuries were higher in Tanner stage 4 than in the other stages (p=0.031). Injuries occurred more commonly in strikers (86.5%), followed by goalkeepers (33.3%), defenders (32.4%), and midfielders (24.7%) (p<0.001). The most common injuries occurred during the game (53.8%), particularly during the first part (45 min) of the game. The relationship between injury and the study variables is shown in Table IV.

Lower extremity injuries (60.9%) were more common, with toe injuries being the leading cause (28.1%) followed by ankle injuries (14.1%). The most common location of upper extremity injury was the wrist (12.5%). The mean age was reported as 13.6±1.6 for knee injuries, 13.5±1.3 for ankle injuries, and 14.7±1.1 for wrist injuries, and a difference was found between the injury region and chronological age (p=0.001).

The most common injury mechanisms in soccer players were dribbling and collisions with another player (38.4%, p=0.001). The most common injury types were fractures (26.8%), strains (24.4%), and sprains (17.1% (p=0.008). Although there was no significant relationship between injury type and Tanner stage (p=0.160), fractures (37.0%) and sprains (37.0%) were most common in stage 4 and strain in stage 3 (31.8%) (p = 0.160). A difference was found between injury type and skeletal age (fracture 14.1±1.7, sprain 14.4±1.7, strain 13.7±1.7, and p=0.036). Additionally, the injury type differed according to the playing position. Fractures were more common in defenders (40.9%) and strains/ sprains in strikers (55.0%) (p=0.027).

Weekly training time (hours/week) was lower in the injury group [(6.1±1.1 hours/week in injury positive group vs 6.7±0.8 hours/week in injury negative group), (p<0.001)] but no difference was detected in the number of training days [(4.7±0.4 day/week in injury positive group vs 4.8±0.3 day/week in injury negative group), (p=0.068)]. The duration of the return to training and/or a game was 26.5±24.2 days. The injury rate was 5.8/1000 h, and a positive correlation

Table IV. Injury and variables in the study group.

Variables	Injury History				p
	Positive		Negative		
	N	Median (min-max)/Mean±SD	N	Median (min-max)/Mean±SD	
Chronological age	81	13.9±1.5	125	13.1±1.4	<0.001
Skeletal age	81	14.0 (11.0-18.0)	125	13.0 (11.0-17.0)	<0.001*
Weight (kg)	81	56.7±12.4	125	50.7±11.8	0.001
Height (cm)	80	168.8±10.6	124	165.4±12.0	0.038
BMI (kg/m^2)	80	19.7±2.4	124	18.3±2.3	<0.001
BMI (p)	80	34.6 (3.2-82.6)	124	24.7 (1.0-82.1)	0.003*
Growth rate (cm/year)	46	6.6±3.8	71	6.1±3.7	0.518
Growth rate SDS	45	0.3±1.3	71	0.5±1.9	0.021
Total body fat %	81	13.9 (9.0-21.9)	125	12.8 (5.9-20.0)	0.104*
FFM%	75	58.1 (27.8-91.0)	118	80.5 (23.3-91.1)	0.972*
Total body water %	75	42.5 (20.4-66.5)	118	58.8 (17.1-66.8)	0.974*
Total abdominal fat %	81	9.7 (3.4-18.4)	125	8.3 (3.0-16.1)	0.043*

BMI: body mass index, FFM: fat-free mass, Mean±SD: mean±standart deviation, p: percentile, SDS: standart deviation score, *Mann Whitney U test.

was found with chronological age (rho= 0.477, p<0.001), skeletal age (rho= 0.457, p<0.001), height (rho= 0.333, p=0.003), weight (rho= 440, p<0.001), and BMI (rho= 0.474, p<0.001), and a negative correlation was observed with training hours/week (rho= -0.486, p<0.001). The injury rate of the training time (days) for five days was 5.4/1000 h, and for the four days was 6.8/1000 h (p=0.041). Regression analysis showed that the growth rate of SDS and total body water had an impact on injury risk (Table V).

Discussion

The purpose of the study was to compare the growth and biological maturation of young soccer players to that of their non-athletic, healthy counterparts, as well as to assess injury characteristics, in particular their relationship to biological maturity. Taller height, lower weight and lower BMI observed in the study group clearly demonstrate the benefits of regular training on the body. Cacciari et al.[19] stated that the soccer players were taller than the controls in the pubertal period (14-16 chronological age), however, they found no significant growth differences in soccer players compared to the control group in the prepubertal period. We found that the anthropometrical findings were better in soccer players in all age groups, but the growth rate was not observed to be different at 11.0, 12.0, and 15.0 years old. Moreover, the growth rate was higher in the study group, especially at the predicted growth spurt ages of 13.0, 14.0 years. It was interesting to find that at the age of 16.0 years, the growth rate was higher in the controls than in the players. This result may suggest that players reached their target height on time or earlier than the controls. Moreover, the growth rate was higher in the study group in Tanner stages 1, 2, 3, and 4, but was higher in the control group only at stage 5. This result might be due to the small number of participants in Tanner Stage 5.

While total body fat and abdominal fat percentages were found to be lower in soccer players, total body water and FFM were higher; moreover, these findings were seen in all Tanner stages. Playing soccer also has beneficial effects on the body’s metabolism, as suggested by the positive correlations between total body water, FFM, and the negative correlations between total body fat, total abdominal fat, and abdominal skinfold thickness with training times.

Another important finding was that growth rate had a positive correlation with training time (h/day), but not with the total days of training per week. This result suggests that the training duration is more important than the number of training sessions per week. This shows the importance of adjusting the training time to obtain the maximum benefit by following the growing age.

The peripheral fat thickness, such as triceps, subscapular, thigh, and calf was higher in the study group at the chronological ages of 14.0, 15.0, and 16.0 years old. However, the abdominal skinfold thickness, which is accepted as an indicator of central and visceral obesity, was lower in all ages in the study group. While

Table V. Regression analysis of injury in the study group.

Variables	B	Exp (B)	95% CI for Exp(B)	
			Lower-Upper	p
Age	.358	1.431	.971-2.233	0.114
Growth rate (SDS)	.304	1.356	1.019-1.803	**0.036**
BMI (kg/m^2)	.011	1.011	.691-1.477	0.957
Total body fat%	.268	1.308	1.000-1.711	0.050
Total body water %	-.035	.966	.934-.999	**0.041**
Abdominal skinfold thickness (mm)	-.115	.891	.771-1.031	0.120

B: estimated coefficient, BMI: body mass index, CI: confidence interval, Exp(B): odds ratio, SDS: standart deviation score.

total body fat and FFM continue to increase during the growth spurt, it is known that fat accumulation in the extremities temporarily decreases and fat deposits centrally.[20] Cacciari et al.[19] found that triceps and subscapular skinfold thickness were thinner than controls only in the 12-13.9 years old (chronological age and skeletal age) group, as in the current study. On the other hand, sport-specific training programs increase in intensity and change as age progresses. Akin et al.[21] found that central fatness was higher in wrestling, weightlifting, handball, and taekwondo players, and peripheral fatness was higher in soccer players. These results may suggest that exercises for the upper extremity were neglected in the study group, reflecting the nature of soccer. We believe that to reduce the risk of injury in young athletes, whole-body training programs should be encouraged.

It has previously been shown that playing soccer increases the risk of injury.[22] Soccer is a sport involving movement, speed, frequent changes of direction, and direct contact, with the risk of injury among players.[23] When examining the frequency of sports injuries, a description of the injury is also important. In the literature, sports injuries are classified according to several criteria, such as; emergency admission, medical care needs or reduction of sports activity, and having a time loss of more than 21 days or having a time loss of at least 48 hours in sports activities.[23] In this study, inquiries about the injuries in the last season included hospital or doctor admission and/or the necessity of stopping the activity at the time of injury, the requirement of rest or medical control, and if it occurred during training and/or a game, and/or if it occurred due to another reason. The injury rate in adolescent male soccer players was 5.8/1000 hours. Faude et al.[23] evaluated soccer injuries in children and adolescents and found the injury rate in adolescent soccer players aged between 13 and 19 years to be 2-7/1000 hours.

In the current study, the injury rate was highest in Tanner stage 4. Linder et al.[24] examined the relationship between Tanner stage and injury incidence in junior high school soccer players and found that it was higher in adolescents in Tanner stages 3, 4, and 5 who were more mature. In another study evaluating 122 players, the rate of injury was 21.3% (3.6% in the 10-12 age group, 25.0% in the 13-15 age group, and 28.0% in the 16-18 age group).[25]

More aggressive play and greater risk-taking was associated with maturity and lack of coordination and strength in the males who were mature according to Tanner stage but had a weak grip could also be a factor leading to injury.[26] The expected growth spurt in males coincides with Tanner stages 3 and 4 (13-14 years), and physical growth and puberty which are characterized by many hormonal, emotional, and neurological changes that impact injury.[27] Many studies have reported the high prevalence of sports injuries around the age of growth spurt among adolescent soccer players, especially 6 months before or after the growth spurt age.[28] It was shown that injury risk is higher among taller and heavier adolescent male soccer players. Several studies have reported an increased injury rate among heavier players or players with a high BMI. Higher weights produce greater forces that are supposed to be absorbed through soft tissues and joints.[29] And It was reported that taller players reported more injuries than shorter ones.[30] Our results suggest that maturity could be a risk factor for injury in soccer.

Training time in hours had a more significant relationship with injury rate than the number of training days per week. These results indicate that the planning of training time to conform to the growth rate is essential to reduce the injury rate. Otherwise, specialization in sports at an early age and an increase in training intensity, duration, and frequency may cause overuse injuries.[31] Considering all the findings, growth rate seems to be related to higher injury risk, whereas higher total body water reduces the risk in adolescent male soccer players. It can be deduced that the high range of growth rate increases the risk of injury by increasing the mechanical stress on the musculoskeletal system.[32] The growth rates of at least 0.6 cm/

month, monthly BMI-increase of >0.3 kg/m^2, and decrease in BMI value of at least 0.4 kg/m^2 were found to be potential injury risk factors.[30] Similarly, Rommers et al.[33] found a 15% increase in injury risk per cm of growth per year and identified a greater increase in leg length (cm/year) as an overuse injury risk factor in young soccer players.[30,33]

On the other hand, adequate hydration should be underlined concerning the lower risk of injury in adolescent male soccer players as shown in our study. Williams[34] reported that hydration increases energy, positively affects agility and movement, helps thermoregulation and mental clarity, increases physical performance, and reduces injury risk. However, optimal fluid intake has been studied more extensively in adults than in children and adolescents. This issue needs to be studied further in children and adolescents.

This research has certain limitations. The primary limitation was that the participants' heights from one year ago were self-reported by the participants of parents. However, studies have shown that adolescents' self-reported height and weight are accurate, so although not ideal, we believe this data to be of value.[35] In addition, due to the large number of groups participating at the same time and the participants' reluctance to endure pubertal evaluation due to embarrassment, the evaluation of sexual maturation was also based on self-reported charts rather than physical examination which was another important limitation. Due to the dearth of female professionals in the field, recruiting females from women's soccer teams in Turkey would have been exceedingly difficult. We believe that additional studies evaluating women should be conducted.

In conclusion, playing soccer during the adolescent period is related to better growth and maturity and the risk of injury, and the growth rate of SDS increases this risk. As the impact of injuries varies with maturation status and timing, soccer academies should regularly monitor the maturation status and timing of adolescent soccer players throughout each season with an emphasis on training hours rather than training days, and close monitoring of hydration and nutrition. As adolescents continue to develop physically, their motor and cognitive skills may not yet simultaneously develop, and they are more prone to injury.

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Ethical approval

The study was approved by the Institutional review board of Hacettepe University GO 17/235-04. Informed consent was obtained from all the participants and their parents or guardians.

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: RD, SA, BÜ, NK, OD data collection: RD, GD analysis and interpretation of results: RD, GD, SA, BÜ, NK, OD draft manuscript preparation: RD, SA, GD, BÜ, NK, OD. All authors reviewed and approved the final version of the manuscript.

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Conflict of interest

The authors declare that there is no conflict of interest.

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