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Risk factors for injury in talented soccer and tennis players

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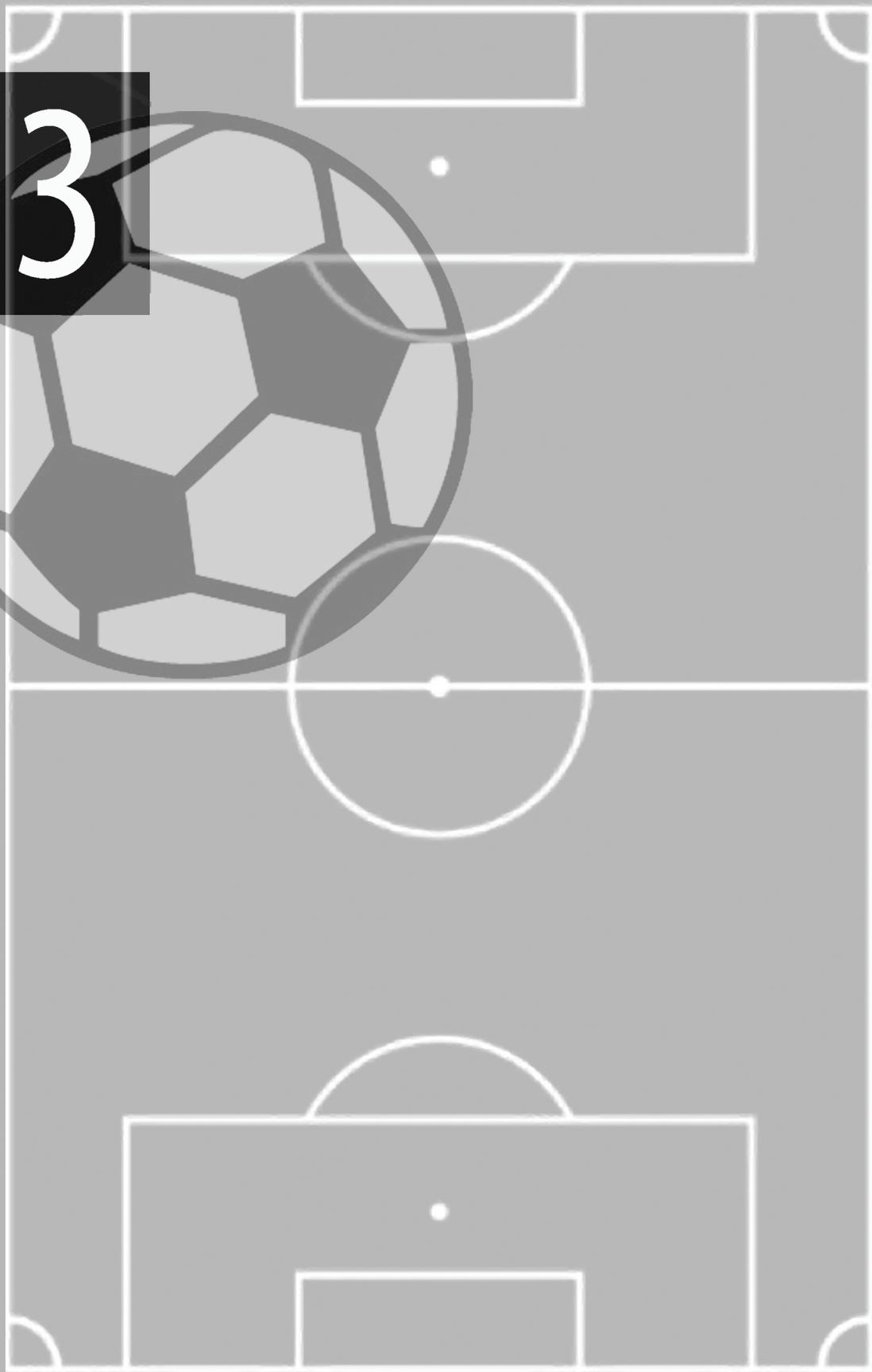
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CHAPTER 3

ANTHROPOMETRIC INJURY RISK FACTORS IN ELITE-STANDARD YOUTH SOCCER

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ABSTRACT

The aim of the study was to investigate whether an increased risk of injury occurrence can be determined through frequent anthropometric measurements in elite-standard youth soccer players. Over the course of one season, we followed 101 male elite-standard youth soccer players between 11 and 19 years of age. Height and body mass were monitored at monthly measurement intervals and fat percentage was assessed every 3 months by use of the sum of skin-fold method. Growth in height (cm), alternations in body mass index (kg/m^2), fat percentage, and fat-free mass index (kg/m^2) were calculated. Injuries were recorded in accordance with the recommendations of the FIFA Consensus Model for Injury Registration. Odds ratio scores and 95% confidence intervals were calculated using binary logistic regression analyses. The following anthropometric injury risk factors were identified: 0.6 centimeter growth per month ($p=0.03$; OR=1.63; 95% CI: 1.06-2.52), 0.3 kg/m^2 increase of body mass index value per month ($p=0.03$; OR=1.61; 95% CI: 1.04-2.49) and low fat percentage; i.e. <7% for players aged 11-16 and <5% for players over 16 years ($p=0.01$; OR=1.81; 95% CI: 1.18-2.76). Individual monitoring of anthropometrics provides useful information to determine increased risk of injury occurrence in elite-standard youth soccer.

Keywords: growth spurt, maturation, sports medicine, football, adolescent

INTRODUCTION

In elite-standard youth soccer, injury occurrence results in a considerable amount of time loss from soccer training and matches [23, 35]. In previous literature, injury rates in elite-standard youth soccer vary from 5.6 injuries per 1000 hours exposure [23] to 37.6 injuries per 1000 match hours [5]. Research also describes that youth athletes are hypothesized to be susceptible to injuries due to growth and maturation [12, 15, 26, 42]. In the current study, growth is defined as becoming taller and refers to growth in height [26]. Regarding maturation, a distinction can be made between timing and tempo. Timing refers to when specific maturational events occur. Differences in injury incidence between earlier and later maturing groups in elite-standard youth soccer are not consistent [23, 24, 43]. A high tempo of maturation and high growth rates may possibly explain the high incidence of injuries that is found around the age of peak height velocity (PHV) [42]. Fast growing adolescents show an increased joint stiffness of the hip, knee and ankle [15] and a reduced flexibility of the lower back and hamstrings [34]. Increased stiffness during the maximal rate of growth, has been linked to an increased injury risk in youth athletes [3]. Moreover, adolescents' cartilaginous structures like the articular surfaces, apophyses and physes, are in and of themselves more at risk for injury than mature bones as a result of growth [3, 14, 32]. It is supposed that after a period of growth, the cartilaginous structures are not immediately able to deal with a level of high stress, which could result in overuse syndromes like Osgood Schlatter disease, Morbus Sever disease [11]. Further, growths' non-linearity and complexity may be of the reasons why adolescents have to deal with a period of clumsiness in motor coordination that may underlie a temporarily higher injury risk [2, 3, 11, 14, 36].

Like growth, alternations in body mass index (BMI) and deviations in fat percentage and fat-free mass have been mentioned as anthropometric factors that could have an influence on injury risk [30]. Alternations in BMI may imply changes in moments of inertia, forces and deformations experienced by various tissues during athletic movement [18]. Furthermore, BMI increases may suggest a high tempo of maturation, as the great BMI increases are age related, in the years around PHV in elite-standard youth soccer [27, 29]. Furthermore, it is considered

that there is an optimal range for fat percentage in terms of injury risk [33]. High fat percentage has been shown to be associated with injury risk, particularly in strain injuries [1]. On the other hand, it is supposed that youth athletes need to have sufficient body- and fat mass to absorb external forces in clashes with opponents and repetitive impact forces during running and shooting [4]. Fat-free mass (FFM) will contribute to this shock absorption and is responsible for generating forces [29]. To avoid injuries, maturing elite-standard youth soccer players must be able to cope with the physical demands of soccer and, therefore, deviating fat percentages and low FFMI-values are potential injury risk factors [22]. Despite the supposed relationship between anthropometrics and injuries in elite-standard youth soccer, research in which anthropometric characteristics and injury occurrence are systematically monitored in youth soccer players is lacking [9, 12]. Therefore, the aim of the study was to investigate whether an increased risk of injury occurrence can be determined through frequent anthropometric measurements in elite-standard youth soccer players. We hypothesized that high growth rate, large BMI alternation (both increase and decrease), having low- or high fat percentages and low FFMI values are anthropometric injury risk factors. Growth and BMI alternations were hypothesized to be associated with injury, because of their strong relationship to the tempo of maturation that results in quick changes in body dimensions [11, 15, 26, 36]. Fat percentage and FFMI were expected to be stand-alone risk factors for injury [1, 9, 29, 30].

METHOD

Study Design

The current study was performed during the 2012-2013 competitive season from September-April and consisted of 8 mesocycles of 4 weeks. As a part of September was pre-season, injury registration started in October. A prospective longitudinal cohort design was used to monitor height, body mass, fat percentage and injuries. Injury risk factors were assessed, i.e., growth, BMI alternations, fat percentage, and FFMI and related to injury occurrence. The study was approved by the local ethics committee of the Center for Human Movement Sciences

of the University of Groningen and was in accordance with the ethical standards for sports medicine [20].

Participants

In total, 101 male elite-standard youth soccer players of 8 teams (U12 n=14; U13 n=15; U14 n=14, U15 n=13, U16 n=12, U 17 n=15, U19 n= 18) of one youth academy participated in the current study. Only outfield players were included, since the load and physical demands of goalkeepers are different from outfield players [40]. U12 through U14 teams trained 4 times a week with a total soccer training duration of 6 hours per week, whereas U15 through U19 teams trained 5 times a week with a total soccer training duration of 9 hours per week. Match duration was 60 (U12 and U13), 70 (U14 and U15), 80 (U16 and U17) or 90 (U19) minutes.

DATA COLLECTION

Anthropometric characteristics

Height and body mass were measured every first Monday of the month, always before practice and at the same time of day. To measure height, a tapeline was fixed on the wall and a sliding horizontal headpiece was placed on the top of the head at a 90-degree angle. Participants were standing erect without shoes and their heels together and head in the Frankfort horizontal plane [39]. Subsequently, monthly growth rates were calculated to the nearest 0.1 decimal place (cm growth/month). Body mass, which was used to determine BMI alternations (kg/m^2 per month) and FFMI (kg/m^2), was measured with an analogue scale to the nearest 0.5 kg. Fat percentage was measured every three months (See Table 1 for a time schedule).

Table 1. Time schedule anthropometric measurements.

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Anthropometric	Height	Height	Height	Height	Height	Height	Height	Height
measurements	Body mass	Body mass	Body mass	Body mass	Body mass	Body mass	Body mass	Body mass
	Fat %			Fat %			Fat %	
	Start data collection; twice a week meetings with physiotherapists to discuss the injuries were held							

To calculate the percentage of body fat, four sites of skin-fold measurement were assessed [13]. These included biceps, triceps, subscapular and iliac crest. Calculations of the body fat were based on the equation given by Deurenberg [10]. Players were subdivided into 3 groups: low-, average-, and high fat percentage [33]. Categories and ranges were displayed in Table 2.

One physiotherapist repeatedly performed both the height and body mass measurements. The club physician performed body fat percentage estimations. Minimum and maximum values for the short-term reliability of each anthropometric characteristic were assessed while calculating the typical error of measurement (TEM) and coefficient of variation (CV) [21]. In earlier research, height, body mass, and fat percentage assessments were found to be reliable in highly trained youth soccer players, in which intra-class-correlation values (ICC) varied from 0.99 to 1.00 for height, 0.99 to 1.00 for body mass and 0.92 to 1.00 for fat percentage [7]. Age and maturity status both had no clear effect on ICC [7]. FFMI is calculated by dividing the fat mass by the square of the height. The unit of FFMI is kg/m^2 , in which the most recently assessed height, body mass, and fat percentage were used.

Table 2. Categories and ranges for fat percentage.

Injury risk factor	Categories	Ranges of scores
Fat percentage		
Age 11-16	Low	≤ 6.99
	Average	7 – 13.99
	High	≥ 14
Fat percentage		
Age 17-19	Low	≤ 4.99
	Average	5 – 11.99
	High	≥ 12

Injuries

All players had free access to the medical staff each training session. The members of the medical staff, which consisted of two physiotherapists and one physician, diagnosed the injuries. Twice a week, meetings with physiotherapists took place to record the injuries. Injuries were defined following the recommendations of the FIFA Consensus Model for Injury Registration [17] and included registration of type, severity, mechanism of injury (acute or overuse), and activity (see Figure 1). Slight injuries without time loss from soccer training and matches were only included if medical attention consisted of rehabilitation programs, massages or mobilizations for more than one day. Injuries that occurred preceding the testing window were excluded. From severe injuries (more than 28 days absence from training and match), only the first 2 months after occurrence were included.

Statistical analysis

For each month, participants' anthropometric injury risk factors and injury status were determined. At the end of the testing window, the number of observations reached a total of 696 (101 players * 7 months minus the observations that were excluded from the study). Injury risk factors were included as independent variables and injury occurrence was the dependent variable. Observations were divided into 2 groups:

the experimental group, which consisted of players who had injury in the particular month and the control group, which consisted of non-injured players in the particular month. The age of the participants was recorded in years to 2 decimal places at time of measurement and to create standardized age groups, i.e. a 13-year-old player was defined as a player tested within the age range of 12.50 to 13.49 years. Age was included as a possible co-founder for injury risk because no reference values are available for growth, BMI-alternations, and FFMI. Data were analyzed using binary logistic regression in SPSS 20.0 (SPSS, Chicago, Illinois). Variables were checked for normality by assessments of the bell-shaped symmetrical curve [16]. Continuous injury risk factors that had a p-value below 0.10 were converted into discrete variables [8]. The regression analysis was executed by using the forced entry method. For all injury risk factors, odds ratios (OR) and 95% confidence intervals (CI) were calculated and differences were considered significant when the p-value was less than 0.05. The Hosmer and Lemeshow Goodness-of-Fit Test was performed to determine whether the model fitted the data. The Nagelkerke's R² was calculated to determine the power of the model [31].

RESULTS

Injuries

During the 7-month study, a total of 134 injuries occurred. The injury incidence was 5.9 per 1000 training and match hours. 63 injuries were recorded during matches and 71 injuries were recorded during training sessions. Injury rate in matches was 18.2 per 1000 hours and in training 3,3 per 1000 hours training. Furthermore, 88 injuries occurred traumatically, and 46 injuries were a result of overuse. 25 players suffered no injury during the testing window, 38 players suffered one injury and 38 players suffered multiple injuries. The mean (SD) number of time loss from soccer activities was 14 (15) days. See Figure 1 for an overview of the most prevalent injury types.

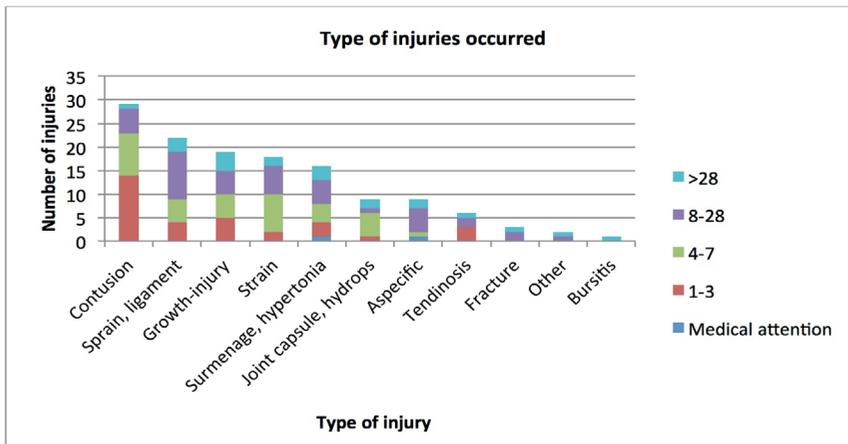


Figure 1. Injury type and severity of injury. Injuries: slight (no absence from training and match, but medical attention was needed); minimal (1-3 days); mild (4-7 days); moderate (8-28 days), severe (more than 28 days).

Injury risk factors

Table 3 shows descriptive statistics for anthropometric characteristics and anthropometric injury risk factors over the different age categories, assessed in October. TEM values for height were 0.3-0.4 and CV values were 0.3. Regarding weight, TEMs varied from 0.5 to 0.7 and CVs were 0.6-0.7. For fat assessments, TEMs varied from 0.6 to 2.2 and CVs varied from 0.5 to 2.2. Table 4 shows descriptive statistics of injury risk factors for the experimental group compared to the control group for different age categories. In most age categories, injured players show higher average growth rates than non-injured players. Furthermore, many players under-16, were categorized as having a low fat percentage, and many players categorized as having a low fat percentage also suffered an injury.

Table 3. Anthropometric characteristics and anthropometric injury risk factors of the elite-standard youth soccer players. Data collected at the start of the study (October).

Age	Total mean	11	12	13	14	15	16	17	18	19
Number of players in October	101	4	23	11	13	13	13	12	7	5
Height (cm)	169.0 (13.1)	151.9 (5.6)	151.3 (6.3)	158.7 (8.0)	168.7 (5.6)	174.8 (8.0)	177.3 (8.3)	175.9 (5.3)	179.1 (7.8)	185.6 (4.7)
Body mass (kg)	56.8 (14.8)	38.4 (6.6)	40.1 (5.5)	47.2 (5.0)	53.9 (6.2)	62.6 (7.4)	66.9 (10.1)	71.6 (10.5)	72.3 (7.3)	79.7 (9.2)
BMI (kg/m ²)	19.7 (3.3)	16.6 (2.1)	17.4 (1.2)	18.7 (1.3)	19.0 (1.9)	20.4 (1.4)	21.2 (2.1)	21.3 (6.8)	22.5 (1.2)	23.1 (1.9)
Fat (%)	7.9 (2.9)	7.4 (2.6)	7.1 (3.2)	8.0 (2.4)	7.7 (3.2)	7.2 (2.1)	8.3 (3.2)	8.0 (3.2)	9.0 (3.8)	10.6 (3.8)
FFMI (kg/m ²)	18.3 (2.2)	15.3(1.5)	16.2 (0.9)	17.2 (0.8)	17.5 (1.6)	18.9 (1.1)	19.4 (1.4)	21.1 (1.7)	20.5 (0.9)	20.6 (1.0)

Results are presented as mean (±SD)
SD, standard deviation, BMI, body mass index, FFMI, fat-free mass index

Table 4. Descriptive statistics of injury risk factors per age category.

Age	11		12		13		14		15		16		17		18		19	
	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured
Number of observations	17	123	100	81	109	79	89	51	47	19	18	51	47	19	18	51	47	19
injured/non-injured																		
Percentage (number of observations)	0 (0)	18 (22)	82 (101)	23 (23)	77 (77)	23 (19)	77 (62)	23 (25)	77 (84)	28 (22)	72 (57)	21 (19)	79 (70)	41 (21)	59 (30)	26 (12)	74 (35)	
Growth (SD)	-	0.5 (0.3)	0.6 (0.4)	0.5 (0.5)	0.7 (0.4)	0.5 (0.4)	0.5 (0.4)	0.4 (0.3)	0.4 (0.3)	0.5 (0.3)	0.5 (0.3)	0.4 (0.3)	0.4 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.2)	0.1 (0.2)	0.1 (0.3)
(cm/month)	-	0.0 (0.2)	0.1 (0.3)	0.1 (0.3)	0.2 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.0 (0.4)	0.0 (0.4)	0.0 (0.3)	0.0 (0.3)	0.0 (0.3)	0.0 (0.2)	0.0 (0.2)	0.0 (0.4)
BMI alternations (kg/m ² /month) (SD)	-	0.0 (0.2)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.0 (0.4)	0.0 (0.4)	0.0 (0.3)	0.0 (0.3)	0.0 (0.3)	0.0 (0.2)	0.0 (0.2)	0.0 (0.4)
Fat																		
Percentage (number of observations)																		
Low	0 (0)	82 (14)	14 (17)	37 (46)	9 (9)	29 (29)	15 (12)	40 (32)	17 (19)	39 (43)	9 (7)	15 (12)	7 (6)	8 (7)	0 (0)	0 (0)	4 (2)	11
Average	0 (0)	18 (3)	4 (5)	41 (50)	14 (14)	46 (46)	9 (7)	37 (30)	6 (6)	38 (41)	18 (14)	49 (39)	15 (13)	67 (60)	37 (19)	51 (26)	19 (9)	(5)43
High	0 (0)	0 (0)	0 (0)	4 (5)	0 (0)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	8 (6)	0 (0)	3 (3)	4 (2)	8 (4)	2 (1)	(20)
FFMI (kg/m ³) (SD)	-	14.9 (0.8)	16.3 (1.0)	16.4 (0.9)	17.4 (0.9)	16.9 (0.9)	17.7 (0.9)	17.9 (1.4)	18.8 (0.9)	18.6 (1.3)	19.1 (1.7)	20.0 (1.3)	20.4 (1.5)	20.7 (1.6)	21.2 (1.3)	21.5 (1.4)	20.6 (0.8)	20.7 (1.1)

BMI, body mass index; FFMI, fat-free mass index

Relation between injury risk factors and injury occurrence

Binary logistic regression analysis showed that players with growth rates of at least 0.6 cm/month had a higher risk for injury ($p=.03$; OR=1.63; 95% CI 1.06-2.52), see Table 5. Furthermore, players showing a monthly BMI-increase of >0.3 kg/m² were at a higher risk for injury ($p=0.03$; OR=1.61; 95% CI 1.04-2.49). A decrease in BMI-value of at least 0.4 kg/m² per month is also associated with injury occurrence ($p=.06$; OR=1.97; 95% CI 0.97-4.00). Regarding fat percentage, players with low fat percentages were at higher risk for injury ($p=.01$; OR=1.81; 95% CI 1.18-2.76) and players with high fat percentage had fewer injuries, although this was not significant ($p=.06$; OR=0.33; 95% CI 0.117-1.04). No significant results were found for FFMI ($p=.43$; OR=1.07; 95% CI 0.91-1.25). The Hosmer and Lemshow Goodness-of-Fit Test revealed that the model fitted the data, $X^2 = 9.86$, $df = 8$, $p = .28$. The Nagelkerke R^2 indicated that the models' explained variance was 7%.

Table 5. Binary regression of injury risk factors.

Injury risk factor	Border values	CI (95%)			<i>p</i>
		OR			
Growth (cm/month)	≥ 0.6	1.63*	1.06	2.52	0.03
BMI-increase (kg/m ² /month)	≥ 0.3	1.61*	1.04	2.49	0.03
BMI-decrease (kg/m ² /month)	≤ -0.4	1.97	0.97	4.00	0.06
Fat percentage					
Low		1.81*	1.18	2.76	0.01
High		0.33	0.11	1.04	0.06
FFMI (kg/m ²)		1.07	0.91	1.25	0.43

* Difference between injured and non-injured players significant at $p<0.05$ level. OR, odds ratio; CI, confidence interval; *p*, *p*-value; BMI, body mass index; FFMI, fat-free mass index.

DISCUSSION

The aim of the study was to investigate whether an increased risk of injury occurrence can be determined through frequent anthropometric measurements in elite-standard youth soccer players.. Our findings demonstrated that anthropometric characteristics are indeed related to injuries in elite-standard youth soccer players. Growth, BMI increase and having a low fat percentage have been identified as anthropometric injury risk factors. The methodological approach advances current

knowledge, because no studies have monitored anthropometric characteristics and injuries in a longitudinal design so far. The current study's injury incidence (5.9/1000 training and match hours) was slightly higher, when compared with previous literature (5.6 injuries per 1000 hours exposure) [25]. The mean (SD) time loss from soccer activities in the current study was 14 (15) days, which was slightly lower than the average time loss of 21.9 (33.63) days that was described by Price [35].

Interpreting anthropometric injury risk factors

Youth players who grow at least 0.6 cm in the previous month are at higher risk to suffer an injury. This particularly holds true for players around the age of their PHV, who frequently show monthly growth rates of at least 0.6 cm. Regarding the relative risk, the odds ratio score for growth was 1.63. This indicates that players growing at least 0.6 cm per month have at least 1.63-fold greater chance to suffer an injury as compared with those who stay at the same height. In earlier literature, maximum growth rates from 8 cm/year [27], 9 cm/year [44] and 9.7 cm/year [34] in elite-standard youth soccer players were comparable with the growth rates found in the current study. However, a clear link between high growth rate and injuries has never been demonstrated. The relationship between high growth rates and injuries provides more insight into the injury problem between the year before PHV to the year of PHV [12, 43].

A similar relative risk was found for a monthly increase in BMI-value of at least 0.3 kg/m² (odds ratio of 1.61). In earlier research, large BMI increases were found in youth athletes as well [27]. However, monthly BMI increases have never been monitored in combination with an accurate injury registration in youth athletes. When interpreting the relationship between BMI increases and injuries in youth athletes, it is essential to consider whether the increase is greater than what may be expected with normal growth and maturation [28]. Although, the relationship between BMI decreases and injury occurrence was non-significant in this study, BMI decreases can be meaningful. Coaches and medical staff should be aware of the presence of large BMI decreases in elite-standard youth soccer [9, 30].

Chapter Three

Players having a low fat percentage are at significantly higher risk for injuries (odds ratio score of 1.81), while a high body fat percentage did not increase injury risk. In earlier literature, fat percentages in elite-standard youth soccer ranged from 11.8 (2.6) in U15 teams [19] to 11.9 (2.5) in U14 [25] and U19 teams [37]. However, literature in which body fat percentage is linked to injuries is lacking, and optimal values for elite-standard youth soccer players were not defined in literature [12, 38]. Our classification was therefore based on those composed for wrestlers [33], but was useful to identify players at higher risk for injuries due to body fat percentage nevertheless. We support the notion that more research is needed to compose ranges of recommended fat percentages in elite-standard youth soccer [38]. Outcomes of the current study can contribute to this.

Methodological considerations

Fat measurements occurred every three months. However, conducting monthly fat estimations would have given more accurate values, as fat percentage is supposed to be variable and influenced by growth and maturation [6, 29]. Moreover, the applicability of anthropometric injury risk factors will differ between age groups. The identified anthropometric injury risk factors focus in particular on the tempo of maturation, which peaks around the age of 13-14 [25, 41]. Players aged 16-19 rarely show monthly growth rates higher than 0.6 cm (Table 4). It is very likely that during the late adolescent years, other risk factors may provide a better explanation. For instance, adolescents' physical and psychological demands, which are experienced more highly in the late adolescent years, are the underlying reasons for their resultant injuries [12]. Monitoring of individual exposure, stress, and recovery can provide better insight into the load undertaken by each player [5]. In addition, dietary intake may play a role [9].

Conclusions

The current study adds new insights into the relationship between anthropometric characteristics and injuries in elite-standard youth soccer. Our findings demonstrated that anthropometric injury risk factors, i.e., growth and BMI-increase, as well as low fat percentage can be used to recognize elite-standard youth soccer players who are at risk of injury and this may play a role in prevention strategies.

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