Physical Therapy in Sport 58 (2022) 106–116

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Normative values and changes in range of motion, strength, and functional performance over 1 year in adolescent female football players: Data from 418 players in the Karolinska football Injury Cohort study

Anne Fältström [a, b, c, *], Eva Skillgate [a, d], Ulrika Tranaeus [d, e], Nathan Weiss [a, d], Henrik Källberg [a, f], Victor Lyberg [a], Mathias Nomme [a], Nicolai Thome [a], Truls Omsland [a], Eirik Pedersen [a], Martin Hägglund [b, g, h], Markus Waldén [g, h, i, j], Martin Asker [a, d, k]

[a] Department of Health Promotion Science, Musculoskeletal & Sports Injury Epidemiology Center, Sophiahemmet University, Stockholm, Sweden
[b] Unit of Physiotherapy, Department of Health, Medicine and Caring Sciences, Linköping University, Linköping, Sweden
[c] Region Jönköping County, Rehabilitation Centre, Ryhov County Hospital, Jönköping, Sweden
[d] Unit of Intervention and Implementation for Worker Health, Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden
[e] Department of Physiology, Nutrition, Biomechanic, The Swedish School of Sport and Health Sciences, Stockholm, Sweden
[f] Unit of Analysis, Department of Public Health, Analysis and Data Management, Public Health Agency of Sweden, Stockholm, Sweden
[g] Football Research Group, Linköping, Sweden
[h] Sport Without Injury ProgrammE (SWIPE), Linköping University, Linköping, Sweden
[i] Unit of Public Health, Department of Health, Medicine and Caring Sciences, Linköping University, Linköping, Sweden
[j] GHP Ortho Center Skåne, Malmö, Sweden
[k] Naprapathögskolan, Scandinavian College of Naprapathic Manual Medicine, Stockholm, Sweden

ARTICLE INFO

Article history:
Received 12 July 2022
Received in revised form
3 October 2022
Accepted 4 October 2022

Keywords:
Performance
Soccer
Strength
Youth
Women
Screening

ABSTRACT

Objective: To study normative values of range of motion (ROM), strength, and functional performance and investigate changes over 1 year in adolescent female football players.
Design: Cross-sectional.
Participants: 418 adolescent female football players aged 12–17 years.
Main outcome measures: The physical characteristic assessments included (1) ROM assessment of the trunk, hips, and ankles; (2) strength measures (maximal isometric and eccentric strength for the trunk, hips, and knees, and strength endurance for the neck, back, trunk and calves), and (3) functional performance (the one-leg long box jump test and the square hop test).
Results: Older players were stronger, but not when normalized to body weight. Only small differences in ROM regarding age were found. ROM increased over 1 year in most measurements with the largest change in hip external rotation, which increased by 6–7° (Cohen's $d = 0.83–0.87$). Hip ($d = 0.28–1.07$) and knee ($d = 0.38–0.53$) muscle strength and the square hop test ($d = 0.71–0.99$) improved over 1 year.
Conclusions: Normative values for ROM and strength assessments of neck, back, trunk, hips, knees, calves and ankles are presented for adolescent female football players. Generally, fluctuations in ROM were small with little clinical meaning, whereas strength improved over 1 year.

1. Introduction

Football is the most popular female sport in the world with more than 13 million players in organized clubs, and there are more than 3 million players in the age group under 18 years (FIFA, 2019). Female adolescent football players have a high risk of injury and most injuries are located in the lower limbs followed by the trunk

* Corresponding author. Department of Health Promotion Science, Musculoskeletal & Sports Injury Epidemiology Center, Sophiahemmet University, Stockholm, Sweden.
E-mail address: anne.faltstrom@shh.se (A. Fältström).

https://doi.org/10.1016/j.ptsp.2022.10.003
1466-853X/

and upper limbs (Robles-Palazón et al., 2021). Screening tests to identify players who are at high risk for injury and, in turn, guide injury prevention measures, often involve a combination of clinical measures, functional performance tests, and patient-reported outcomes (G. J. Davies, McCarty, Provencher, & Manske, 2017). Screening tests are also used to measure performance in athletes (Bishop, Read, McCubbine, & Turner, 2021), for progression during rehabilitation and for return to sport decisions (van Melick et al., 2020). Therefore, it is important as a researcher, clinician, or coach to have appropriate normative reference values for different defined populations (e.g., according to sex, age, or sport) to make it possible to assess and evaluate normal and abnormal values when screening athletes (Risberg et al., 2018; Sankar, Laird, & Baldwin, 2012). Normative values can also be used as a comparison tool for primary care physicians and other professions, to set rehabilitation goals, and for research. It is also important to know how these values may change over time. However, it is important to be specific when reporting normative values since data may differ with regards to e.g., sex, age, body weight and sport (Harbo, Brincks, & Andersen, 2012; Onate et al., 2018).

To our knowledge, there are no studies providing normative data, including potential changes over a longer time, for female adolescent football players on range of motion (ROM), strength measures and functional performance. Therefore, the aim of this study was to investigate and establish normative values in different screening tests and to investigate if these values change over 1 year in adolescent female football players.

2. Methods

Details about the study design, definitions and data collection procedures in the Karolinska football Injury Cohort (KIC) study are reported elsewhere (Tranaeus et al., 2022), and are therefore only briefly described here.

2.1. Design

This study reports cross-sectional baseline and follow-up data.

2.2. Participants

Twenty-eight local Swedish football teams from a metropolitan area with adolescent female football players aged 12–19 years from the two highest divisions were asked to participate in the study. One team and 4 players from different teams declined to participate; a total of 418 players from 27 teams were included and performed the tests at baseline. In addition, the first 106 players included from 11 teams were re-tested after 1 year. All players and their parents or legal guardians (players <15 years) received oral and written information about the study and signed written consent. The study was approved by the Swedish Ethical Review Authority (Dnr 2016/1251-31/4).

2.3. Procedures

The tests were conducted in indoors facilities during weekends at different times in the football season. Before the testing session, players completed a standardized 7-min warm-up programme comprising 4 min of jogging, 10 squats, 10 squat jumps and 10 unilateral lunges. The tests took approximately 60 min per player to complete. The tests included ROM assessment (of the trunk, hips, and ankles), maximal strength measures (isometric and eccentric for the hips, isometric for the trunk and knees, and endurance for neck, back, trunk, and calves) and functional performance with the one-leg long box jump (OLLBJ) test (G. J. Davies et al., 2017; van Melick et al., 2020), and the modified square hop test (Caffrey, Docherty, Schrader, & Klossner, 2009; Gustavsson et al., 2006). All tests are described in detail in Table 1. Intrarater and interrater reliability and minimal detectable change (MDC) were also calculated for all the tests and are provided in detail in the Supplementary Material.

2.3.1. ROM assessment

ROM was measured for active trunk rotation (Asker, Waldén, Källberg, Holm, & Skillgate, 2017; Johnson, Kim, Yu, Saliba, & Grindstaff, 2012), passive hip flexion and abduction in supine position and passive hip extension, internal and external rotation in prone position (Prather et al., 2010; Sankar et al., 2012), and weight-bearing ankle dorsiflexion (Konor, Morton, Eckerson, & Grindstaff, 2012).

2.3.2. Strength measurements

Strength measurements included isometric trunk rotational strength (Andre et al., 2012), hip flexion, extension, adduction, abduction, knee extension strength (Thorborg, Bandholm, & Hölmich, 2013), and eccentric hip abduction and adduction strength (Thorborg, Couppé, Petersen, Magnusson, & Hölmich, 2011) measured with a hand-held dynamometer (MicroFet2, Hoggan Health Industries inc. West Jordan, UT, USA) (Kelln, McKeon, Gontkof, & Hertel, 2008). Strength was measured for endurance of deep neck flexor muscles (Asker et al., 2017), back extensors (modified Biering-Sörensen test) (Demoulin, Vanderthommen, Duysens, & Crielaard, 2006; Moreau, Green, Johnson, & Moreau, 2001) and ankle plantarflexion muscles (calf heel raises) (Dennis, Finch, Elliott, & Farhart, 2008).

2.3.3. Functional performance tests

A modified OLLBJ (G. J. Davies et al., 2017; van Melick et al., 2020) and square hop test were performed to assess the player's unilateral jump performance (Caffrey et al., 2009; Gustavsson et al., 2006).

2.4. Statistical analyses

Descriptive statistics are presented as means ± standard deviation (SD) or 95% confidence interval (CI) for the total cohort (n = 418), divided into age groups: 12 years (n = 97, 23%), 13 years (n = 157, 38%), 14 years (n = 91, 22%), 15–17 years (n = 73, 17%) and for the sub-cohort followed for 1 year (n = 106). The sub-cohort included players aged 12 years (n = 19, 18%), 13 years (n = 21, 20%), 14 years (n = 39, 37%), 15–17 years (n = 27, 25%) at baseline. Normality and homogeneity of variance were evaluated for continuous data. The mean value for the 3 different measures was used for ROM and maximum values were used for the strength measurements. Values are reported separately for the dominant (preferred kicking leg) and non-dominant leg. The strength measurements were also normalized to body weight and reported in Newton/kg. Paired-sample t tests, Wilcoxon's test (OLLBJ test) and McNemar's test (on the number that completed the cranio-cervical flexion test) were used to compare differences between baseline and the 1-year follow-up. Changes from baseline to follow-up are reported as mean percentage values. Effect sizes (ESs) are presented as Cohen's d or odds ratios (ORs), where $d = 0.2$ indicates a small effect, $d = 0.5$ is a medium effect, and $d = 0.8$ is a large effect. Intrarater and interrater reliability were calculated for the tests with intraclass correlation (ICC) and Cohen's kappa (for the cranio-cervical flexion test) to detect the conformity of the intrarater and interrater measurements. The standard error of measurement (SEM) for each ICC estimate was calculated as $SD \times \sqrt{(1 - ICC)}$. The SEM was used to calculate the minimal detectable change with the

Table 1
Description and scoring of the different tests.

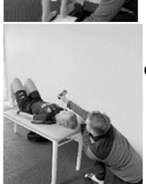
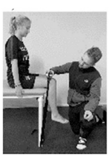
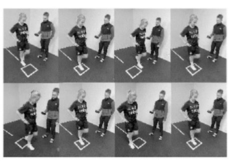
Outcome measures	Description and scoring
Range of motion (ROM)	
Trunk (1) (2)    	Active trunk rotation ROM measured in a modified seated rotation test, and a in a lunge position half-kneeling rotation test on a gym mat graded with 5-degree increments. The player was instructed to maximally rotate alternating between right and left: (1) in a cross-legged position and (2) in a lunge position on the dominant and non-dominant leg measuring the rotational degrees in the end range. In the 3 separate positions, 3 repetitions were performed in each direction. The mean value for each position was used for analysis.
Hip (1) (2) (3)    (4) (5)  	Passive hip ROM using a universal goniometer was measured in supine position (1) flexion and (2) abduction and in prone position (3) extension, (4) internal and (5) external rotation. The endpoint to measure ROM was determined to when a firm end feel was achieved, indicated by a motion of the pelvis. Three consecutive measurements for each position were performed for both the dominant and the non-dominant leg. The mean value for each position was used for analyses.
Foot 	Weight-bearing—lunge ankle dorsal flexion (DF) ROM measured with the player's foot placed on a metric ruler 10 cm away from a wall. The player was instructed to lunge forward until contact with the wall was achieved without allowing the heel to lift off the ground. Three warm-up trials were performed to familiarize the player with the test before measuring 3 trials and the mean value was used for the analysis. The maximal DF ROM was measured with a digital inclinometer (Clinometer, Plaincode, Stephanskirchen, Germany) in degrees and the distance from the wall to the greater toe was measured in centimetres. Three trials were measured, and the mean value was used for the analysis.
 **es: endurance**	
	Deep neck flexor muscle endurance was assessed through a modified version of the cranio-cervical flexion test with a pressure sensor (Stabilizer Pressure Bio-Feedback, Chattanooga Group Inc, Hixon, TN). The test consists of a pre-test and an endurance test. In the pre-test, the player was positioned in a supine position on an examination table and instructed to perform a gentle cranio-cervical flexion to increase the pressure starting from a baseline target pressure (TP) of 20 mmHg and then maintain the pressure for 3 × 3 s, with a 3-s rest

Table 1 (*continued*)

Outcome measures	Description and scoring
	between each contraction. If the player was able to perform this task, she was instructed to increase the pressure to 22 mmHg and keep the pressure for another 3 × 3 s. This was repeated with a 2-mmHg increase until the player reached 30 mmHg. If the player was able to perform the pre-test, the endurance test was then performed with the same setup. However, the player was instructed to hold each contraction at the TP for 3 × 10 s with a 10 s rest between contractions. The highest completed TP with a full set of contractions (3 × 10 s) was registered and later used for analysis.
Back 	Isometric back extensor endurance was assessed by the modified Biering-Sörensen test. The player's lower body was supported on an examination table in prone position with 3 straps and the anterior-superior iliac spine was aligned with the edge of the table. Before the assessment, the player completed a shorter warm-up trial to orient the desired sagittal plane target angle. The player was instructed to keep her arms folded across the chest throughout the procedure and isometrically maintain the upper body in a horizontal position until failure when the time elapsed was registered. A digital inclinometer (Clinometer, Plaincode, Stephanskirchen, Germany) was placed on a metric ruler at the level of T5 in the thoracic spine to monitor sagittal plane movement.
Calf 	Ankle plantar flexion muscle endurance was investigated using unilateral weight-bearing calf heel raises. The maximal height that the player achieved during one barefoot calf heel raise was marked with a metric ruler. The player was then instructed to perform maximum unilateral barefoot heel raises continuously until the player failed to reach the marked maximal height, guided by a metronome to standardize the pace (1 s concentric, 1 s eccentric contraction). The same procedure was then conducted on the opposite foot. The number of repetitions accomplished was used in the analysis.
Strength measures: isometric and eccentric	
Trunk 	Isometric trunk rotational strength was measured in a modified standing wood chopper test utilizing a force gauge to evaluate force output (RS Pro Digital Force Gauge, RS Components Ltd., Corby, UK). In this modified test, the player held a handle attached to the force gauge at shoulder height in a standing position. The player was instructed to generate force through her trunk and rotate for 5 s while maintaining straight arms. Three consecutive repetitions were performed in each direction and the maximal force output was used for analysis.
Hip and knee 1) (2) (3)    (4) (5) (6) (7)   	Isometric (1) hip flexion, (2) extension, (3) adduction and (4) abduction strength as well as (5) eccentric hip abduction and (6) adduction strength was measured with a hand-held dynamometer (HHD) (MicroFet2, Hoggan Health Industries inc. West Jordan, UT, USA). Isometric (7) knee extension strength was measured with an HHD with the player in a seated position with the knee joint in 90-degrees of flexion. Before executing the strength tests, 2 submaximal isometric contractions were performed in each direction to familiarize the player with the procedures. Three isometric contractions with gradually increasing power output for 5 s, and 3 maximally eccentric contractions for 3 s were performed in the isometric and eccentric tests, respectively, with a 10-s rest between contractions. The maximal power output for each position was used for analysis.

(*continued on next page*)

Table 1 (*continued*)

Outcome measures	Description and scoring
	
Functional performance	
The one-leg long box jump test (OLLBJ)  	In the OLLBJ, the starting position was calculated by dividing the player's height (cm) by 1.6 (height/1.6). The player was then instructed to stand on 1 leg on the starting position and then jump on 1 leg directed inside the boundaries of the square and maintain balance after landing. Three warm-up trials and 5 consecutive test trials were performed on each leg. The total number of approved trials on each leg was used in the analysis.
Square hop test 	The player was instructed to jump in a clockwise direction on 1 leg in and out of the square as many times as possible for 15 s. The player performed 2 warm-up trials on each foot before executing the test.

corresponding 95% CI, (MDC)95, as 1.96 × SEM × $\sqrt{2}$. The significance level was set at $p < 0.05$. Statistical analyses were performed using SPSS Statistics for Windows (IBM SPSS Statistics for Windows, Version 27.0. IBM, Armonk, NY). We used R version 4.02 and the psych package for ICC and Cohen's kappa.

3. Results

The characteristics of the 418 adolescent female football players at baseline and specific to the different age groups and the sub-cohort of 106 players before and after the 1-year follow-up (12.2 ± 0.7 months) are presented in Table 2. None of the 106 players followed for 1 year changed club during the follow-up.

Normative values and changes in the sub-cohort from baseline to the 1-year follow-up for the different tests are presented in Tables 3–6. Generally, there were no differences regarding ROM regarding age except for external and internal hip rotation. Older players were stronger in the hip and knee muscles, but not when normalized to body weight. There were no significant differences between the dominant and non-dominant legs in the 418 players. The intrarater and interrater reliability for all tests ranged from 0.40 to 1.00 and 0.30 to 0.98, respectively (Supplementary Material).

3.1. Changes in ROM over 1 year

Trunk ROM decreased in all measurements, except for the in-lunge rotation test with rotation to the left and right, left leg in front (Cohen's d = −0.27 to −0.51) (Table 3). Hip, knee, and foot ROM increased slightly in both dominant and non-dominant legs in all directions (Cohen's d = 0.22–0.89) with the largest change seen in external hip rotation, which increased by 6–7° (19%, Cohen's d = 0.83–0.87) (Table 4). All the changes were below the MDC (Supplementary Material).

3.2. Changes in strength measurements over 1 year

Trunk strength (Wood chopper test) to the left increased slightly (Cohen's d = 0.37). The number of players who completed the cranio-cervical flexion test decreased significantly ($p < 0.001$; OR, 5.33) (Table 3). Hip muscle strength increased in both the dominant and non-dominant legs in all directions (9%–24%, Cohen's d = 0.23–1.07) and so did knee extension strength in both the dominant and non-dominant legs (22%–26%, Cohen's d = 0.38–0.53) (Table 5). All the changes were below the MDC (Supplementary Material).

Strength normalized to body weight increased in hip extension (12%–15%, Cohen's d = 0.35–0.37), isometric hip abduction (13%–14%, Cohen's d = 0.34–0.43), eccentric hip abduction (15%–16%, Cohen's d = 0.55–0.76), and knee extension for the non-dominant leg (18%, Cohen's d = 0.29) (Table 6).

3.3. Changes in functional performance over 1 year

Players' performance in the square hop test increased significantly for the dominant (mean, 2 hops; 95% CI, 2 to 3 hops; Cohen's d = 0.71) and non-dominant leg (mean, 4; 95% CI, 3 to 4 hops; Cohen's d = 0.99) (Table 5); the latter exceeded the MDC of 2.5 hops (Supplementary Material).

4. Discussion

Extensive normative data, reference values and changes over 1 year in adolescent female football players for common clinical tests measuring ROM, strength, and functional performance were established and presented in this study. We chose to include these field friendly tests for different joints, and for the neck, back, and trunk, because although most injuries are located in the lower extremities, injuries to the groin and lumbar spine are also

Table 2
Characteristics of the adolescent female football players at baseline (n = 418) and at the 1-year follow-up (n = 106 players).

	Total cohort (12–17 years)		Total cohort divided into age groups				Sub-cohort (12–17 years)	
	N		12 years (n = 97)	13 years (n = 157)	14 years (n = 91)	15–17 years (n = 73)	Baseline (n = 106)	Follow-up (n = 106)
Age, years	418	13.9 ± 1.1	12.7 ± 0.2	13.4 ± 0.3	14.5 ± 0.3	15.8 ± 0.6	14.3 ± 1.2	15.3 ± 1.2
Height, cm	417	163 ± 6.8	160 ± 6.4	161 ± 6.5	165 ± 5.7	168 ± 5.8	163 ± 6.5	165 ± 5.6[a]
Body mass, kg	417	53 ± 9.0	48 ± 7.5	51 ± 7.7	57 ± 7.6	61 ± 7.6	54 ± 8.4	58 ± 7.7[a]
Body mass index, kg/m^2	416	20.1 ± 2.5	18.8 ± 2.2	19.6 ± 2.2	20.9 ± 2.4	21.8 ± 2.1	20.4 ± 2.4	21.1 ± 2.4[a]
Menarche, n (%)	417	279 (67)	35 (36)	91 (58)	82 (90)	71 (97)	78 (74)	–
Age at menarche	416	12.4 ± 1.0	11.9 ± 0.9	12.3 ± 0.9	12.7 ± 1.1	12.6 ± 1.1	12.5 ± 1.2	–
Years playing organized football	416	7.0 ± 2.2	6.0 ± 1.9	6.3 ± 1.8	7.5 ± 1.8	9.2 ± 1.7	7.3 ± 2.3	–
Dominant leg, n (%)	418							
Right		398 (95)	95 (98)	148 (94)	87 (96)	68 (93)	98 (92)	–
Left		17 (4)	2 (2)	8 (5)	4 (4)	3 (4)	6 (6)	–
Both		3 (1)	0 (0)	1 (1)	0 (0)	2 (3)	2 (2)	–
Playing position, n (%)	413							
Goalkeeper		33 (8)	6 (6)	10 (6)	9 (10)	8 (11)	7 (7)	8 (8)
Defender		130 (31)	37 (38)	45 (29)	25 (28)	23 (32)	33 (32)	38 (36)
Midfielder		168 (41)	29 (30)	79 (51)	36 (40)	24 (33)	44 (43)	43 (41)
Forward		82 (20)	25 (26)	21 (14)	19 (21)	17 (24)	19 (18)	17 (16)
Football matches/week, n	418	1.5 ± 0.6	1.6 ± 0.6	1.5 ± 0.6	1.4 ± 0.7	1.2 ± 0.6	1.5 ± 0.8	1.7 ± 0.9
Football training, h/week	418	5.0 ± 1.8	4.6 ± 1.5	5.0 ± 1.6	5.0 ± 1.7	5.4 ± 2.6	5.5 ± 2.5	5.5 ± 2.4
Other training with football team, h/week	416	1.6 ± 1.4	1.4 ± 1.2	1.5 ± 1.3	1.5 ± 1.1	2.2 ± 1.8	1.8 ± 1.7	1.8 ± 1.3
Other training (not football), n (%)	418	135 (32)	33 (34)	55 (36)	23 (25)	23 (32)	24 (23)	33 (31)
Other training (not football), h/week	418	2.7 ± 2.0	2.5 ± 2.1	2.4 ± 1.7	2.7 ± 2.2	3.5 ± 2.4	2.3 ± 1.1	2.1 ± 1.1

Values are reported as means ± standard deviation or n (%). The values regarding training/match are means of the preceding 6 months.
[a] Missing value from 1 player.

Table 3
Results from the neck, back and trunk tests.

Neck, back and trunk tests	Total cohort		Total cohort divided into age groups				Sub-cohort[a]		Change in sub-cohort			
	12–17 years (N = 418)		12 years (n = 97)	13 years (n = 157)	14 years (n = 91)	15–17 years (n = 73)	12–17 years (n = 106)		Follow-up – baseline (n = 106)			
	N	Baseline (95% CI)	Baseline (95% CI)				Baseline (95% CI)	Follow-up (95% CI)	%	Mean (95% CI)	*p* value	Cohen's *d* or OR
ROM, range of motion, degrees												
Seated rotation test, right	418	71 (70–72)	73 (70–75)	72 (71–74)	68 (65–70)	68 (65–71)	72 (70–74)	66 (64–68)	−7	−6 (−8 to −4)	**<0.001**	−0.51
Seated rotation test, left	418	70 (69–72)	71 (69–73)	72 (70–74)	68 (65–70)	69 (67–72)	71 (69–73)	68 (66–70)	−3	−3 (−5 to −1)	**0.006**	−0.27
In lunge position half-kneeling rotation test												
Rotation to the right, right leg in front	417	85 (84–87)	87 (84–89)	89 (86–91)	81 (78–86)	82 (78–85)	87 (85–89)	84 (81–86)	−3	−3 (−5 to −1)	**0.007**	−0.27
Rotation to the right, left leg in front	417	92 (91–94)	91 (88–95)	95 (92–98)	90 (86–94)	90 (86–94)	99 (97–102)	95 (92–99)	−3	−4 (−6 to 0)	0.068	−0.18
Rotation to the left, left leg in front	417	85 (84–87)	85 (82–88)	88 (86–91)	82 (79–85)	83 (80–85)	86 (84–88)	86 (83–89)	1	0 (−3 to 3)	0.809	−0.02
Rotation to the left, right leg in front	417	91 (89–93)	89 (86–93)	93 (90–96)	90 (86–94)	89 (85–93)	98 (96–101)	91 (88–95)	−7	−7 (−10 to −3)	**<0.001**	−0.37
Strength tests, Newton												
Wood chopper test, right	414	56 (54–57)	50 (47–53)	57 (54–59)	55 (52–58)	62 (59–65)	55 (52–58)	59 (56–62)	10	3 (0–6)	0.056	0.19
Wood chopper test, left	414	58 (56–59)	51 (48–54)	60 (57–62)	58 (55–60)	63 (60–66)	56 (53–59)	62 (59–66)	14	6 (3–9)	**<0.001**	0.37
Endurance												
Fulfilled cranio-cervical pre-flexion test, n (%)	417	75 (18)	11 (11)	21 (13)	21 (23)	22 (30)	52 (49)	16 (15)			**<0.001**	5.33
Cranio-cervical flexion test, mmHg	74	26 (25–27)	25 (24–26)	25 (24–26)	26 (25–27)	27 (26–28)	26 (25–27)	26 (24–28)	−6	−2 (−4 to 1)	0.121	−0.54
Biering-Sörensen test, s	417	134 (129–140)	130 (116–143)	130 (122–138)	138 (126–149)	146 (135–157)	140 (128–151)	132 (123–141)	6	−8 (−17 to 2)	0.110	−0.16

Values are reported as the mean (range of motion) and max (strength) value of 3 repetitions. *p* values in bold type are significant. Effect size measured as Cohen's *d*, where *d* = 0.2 indicates a small effect, *d* = 0.5 indicates a medium effect, and *d* = 0.8 indicates a large effect. CI, confidence interval. OR, odds ratio.
[a] Missing value from 0 to 1 player in the different tests both at baseline and at follow-up.

Table 4
Results from the tests for lower limb range of motion.

	Total cohort		Total cohort divided into age groups				Sub-cohort[a]		Change in sub-cohort			
	12–17 years (N = 418)		12 years (n = 97)	13 years (n = 157)	14 years (n = 91)	15–17 years (n = 73)	12–17 years (n = 106)		Follow-up − baseline (n = 106)			
	N	Baseline (95% CI)	Baseline (95% CI)				Baseline (95% CI)	Follow-up (95% CI)	%	Mean (95% CI)	*p* value	Cohen's *d*
Hip range of motion, degrees												
Flexion												
Dominant	418	121 (120–122)	122 (120–123)	123 (122–125)	117 (115–119)	119 (117–122)	114 (113–116)	119 (117–121)	5	5 (3–7)	**<0.001**	0.47
Non-dominant	418	122 (121–123)	122 (120–124)	123 (122–125)	120 (117–122)	121 (119–123)	117 (116–119)	121 (119–122)	3	3 (1–5)	**0.002**	0.31
Extension												
Dominant	416	24 (23–25)	25 (23–27)	21 (20–23)	28 (27–30)	23 (21–24)	26 (25–27)	29 (27–31)	20	3 (0–5)	**0.024**	0.22
Non-dominant	416	23 (22–24)	24 (22–26)	21 (20–23)	27 (25–28)	22 (20–23)	26 (25–27)	27 (25–29)	12	1 (−1 to 3)	0.439	0.08
External rotation												
Dominant	417	46 (45–47)	50 (48–53)	47 (46–49)	42 (40–44)	43 (40–45)	37 (36–38)	43 (42–45)	19	7 (5–8)	**<0.001**	0.87
Non-dominant	418	44 (44–46)	49 (47–51)	47 (45–48)	40 (38–42)	41 (39–44)	37 (35–38)	43 (41–44)	19	6 (5–8)	**<0.001**	0.83
Internal rotation												
Dominant	417	44 (43–45)	47 (45–48)	45 (43–46)	42 (41–43)	42 (39–44)	40 (38–41)	44 (42–46)	12	4 (3–6)	**<0.001**	0.57
Non-dominant	418	46 (45–47)	48 (46–49)	46 (45–47)	45 (43–46)	44 (42–46)	43 (42–45)	45 (44–47)	7	2 (1–4)	**0.009**	0.27
Abduction												
Dominant	418	39 (39–40)	40 (39–41)	39 (38–41)	40 (38–41)	38 (37–40)	39 (38–40)	39 (38–41)	1	0 (−1 to 1)	0.685	0.04
Non-dominant	418	40 (39–40)	40 (39–42)	39 (38–40)	40 (38–41)	40 (38–41)	38 (37–40)	39 (38–40)	3	1 (0–2)	0.257	0.12
Ankle range of motion												
Dorsiflexion, degrees												
Dominant	406	42 (41–42)	42 (41–43)	41 (40–42)	43 (41–44)	42 (41–43)	44 (43–45)	46 (43–49)	5	2 (0–5)	0.085	0.17
Non-dominant	407	42 (41–42)	41 (40–42)	41 (41–42)	43 (41–44)	42 (41–44)	44 (43–45)	47 (44–50)	6	3 (0–5)	**0.028**	0.22
Dorsiflexion, cm												
Dominant	417	13 (12–14)	12 (12–13)	13 (12–13)	13 (12–13)	12 (12–13)	12 (11–12)	13 (13–14)	14	1 (1–2)	**<0.001**	0.89
Non-dominant	418	13 (12–13)	13 (12–13)	13 (12–13)	13 (12–13)	12 (12–13)	12 (11–12)	13 (12–13)	12	1 (1–1)	**<0.001**	0.84

Values are reported as the mean value of 3 repetitions. *p* values in bold type are significant. Effect size measured as Cohen's *d*, where $d = 0.2$ indicates a small effect, $d = 0.5$ indicates a medium effect, and $d = 0.8$ indicates a large effect. CI, confidence interval.
[a] Missing value from 0 to 1 player in the different tests both at baseline and at follow-up.

common (Clausen et al., 2014). To our knowledge, there are no studies describing normative data for this specific cohort and for the tests used, reported by age categories. Previous studies differ regarding sex, age, and sports as well as in terms of the joints and muscle groups being investigated. In addition, measuring instructions and techniques differ or are not reported in detail among studies. Therefore, it is difficult to compare the results for normative values in the present study with previous values in the literature. However, the present study can serve as a reference for future studies in the field on adolescent female football players. Research and risk factors studies on adolescent female football players is expected to increase rapidly, because it is the world's biggest sport for girls and it is growing fast.

Data were presented separately for the dominant and non-dominant legs for clinical purposes and for comparability with previous studies that reported normative values (Daloia, Leonardi-Figueiredo, Martinez, & Mattiello-Sverzut, 2018; Risberg et al., 2018). We did not find any significant differences between dominant and non-dominant legs in any of the tests. Previous studies have shown conflicting results, with stronger isometric strength on the dominant side in a Brazilian population of girls aged 5–15 years (Daloia et al., 2018), but elite female handball and football players demonstrated no clinically important difference between the dominant and non-dominant legs in isokinetic quadriceps and hamstrings strength (Risberg et al., 2018). Therefore, in future reports on normative values, the averaged value of the dominant and non-dominant legs to produce a single value could probably be reported for both ROM and strength measurements in adolescent female football players. When screening individual players, however, large side differences in leg strength could be present, especially after an injury, and it is important to detect and report this (Gustavsson et al., 2006).

4.1. Normative ROM data

No differences were found regarding ROM depending on age, except for the external and internal hip rotation tests where older players had decreased ROM of 5–7°. The clinical relevance of this finding is unclear because the minimum clinically important difference for external and internal hip rotation in youth baseball players has been reported previously to be 7.5 and 5.1°, respectively (Bullock, Beck, Collins, Filbay, & Nicholson, 2021).

Normative data for ROM measurements have been reported previously for hip and ankle ROM in different cohorts (McKay et al., 2017; Onate et al., 2018; Sankar et al., 2012). The normative values reported in a general population of girls aged 11–17 years were almost identical to our reported data (Sankar et al., 2012). Compared with our data, lower values for ankle ROM, external and internal hip rotation, but similar hip flexion were reported in a general female population aged 10–19 years in Australia, (McKay et al., 2017). These differences were probably due to active ROM being measured (McKay et al., 2017) instead of passive ROM, as in our study. Ankle dorsiflexion measured with a weight-bearing lunge test was greater (13 vs 10 cm) in our cohort than reported

Table 5
Results from the tests for lower limb strength and functional performance.

Strength tests (Newton) and functional performance	Total cohort		Total cohort divided into age groups				Sub-cohort[a]		Change in sub-cohort			
	12–17 years (N = 418)		12 years (n = 97)	13 years (n = 157)	14 years (n = 91)	15–17 years (n = 73)	12–17 years (n = 106)		Follow-up − baseline (n = 106)			
	N	Baseline (95% CI)	Baseline (95% CI)				Baseline (95% CI)	Follow-up (95% CI)	%	Mean (95% CI)	*p* value	Cohen's *d*
Hip, isometric												
Flexion												
Dominant	418	173 (169–178)	155 (146–164)	172 (165–179)	186 (175–197)	184 (171–196)	187 (177–197)	191 (182–200)	9	4 (−5 to 13)	0.389	0.08
Non-dominant	418	166 (162–171)	147 (139–155)	169 (163–176)	174 (164–185)	175 (163–187)	173 (163–182)	186 (176–195)	16	14 (4–23)	**0.005**	0.28
Extension												
Dominant	417	132 (128–136)	115 (108–122)	130 (125–135)	142 (133–150)	147 (138–156)	135 (127–142)	156 (148–163)	23	21 (15–28)	**<0.001**	0.66
Non-dominant	417	126 (123–130)	108 (102–115)	123 (119–128)	140 (132–148)	140 (132–148)	131 (124–138)	151 (143–158)	21	19 (13–24)	**<0.001**	0.63
Adduction												
Dominant	416	84 (80–87)	79 (74–85)	71 (64–77)	97 (92–102)	100 (95–105)	95 (90–100)	100 (95–105)	9	5 (1–10)	**0.021**	0.23
Non-dominant	417	82 (79–86)	76 (70–81)	71 (65–77)	96 (91–101)	99 (93–104)	94 (89–99)	98 (93–102)	9	4 (−1 to 8)	0.084	0.17
Abduction												
Dominant	417	82 (79–85)	77 (72–83)	71 (65–77)	94 (89–99)	99 (94–104)	89 (84–93)	102 (98–106)	21	14 (9–18)	**<0.001**	0.60
Non-dominant	416	80 (77–83)	76 (70–81)	69 (63–74)	91 (86–96)	95 (90–100)	86 (81–90)	100 (95–104)	21	15 (11–18)	**<0.001**	0.75
Hip, eccentric												
Adduction												
Dominant	415	109 (105–113)	97 (91–104)	92 (84–99)	132 (125–139)	132 (125–139)	129 (122–135)	138 (133–144)	12	10 (5–16)	**<0.001**	0.35
Non-dominant	416	103 (99–107)	91 (85–97)	86 (78–93)	129 (123–136)	126 (119–134)	127 (120–134)	138 (132–144)	13	12 (7–18)	**<0.001**	0.45
Abduction												
Dominant	417	93 (90–97)	82 (76–87)	78 (71–84)	116 (110–121)	115 (109–121)	108 (102–114)	128 (122–133)	23	20 (15–24)	**<0.001**	0.82
Non-dominant	416	93 (89–96)	84 (78–89)	77 (71–84)	112 (106–118)	115 (110–120)	103 (98–108)	124 (119–129)	24	22 (18–26)	**<0.001**	1.07
Knee, isometric												
Extension												
Dominant	418	232 (225–239)	214 (201–227)	231 (222–240)	236 (221–251)	253 (234–272)	227 (213–241)	253 (240–266)	22	26 (13–39)	**<0.001**	0.38
Non-dominant	417	221 (215–227)	201 (190–213)	219 (211–228)	227 (214–241)	240 (223–259)	213 (200–225)	247 (233–260)	26	34 (22–47)	**<0.001**	0.53
Endurance, repetitions												
Calf heel raise test												
Dominant	414	12 (11–14)	14 (10–19)	12 (11–14)	9 (8–11)	14 (12–15)	10 (8–11)	9 (8–10)	35	−1 (−2 to 0)	0.200	0.13
Non-dominant	414	12 (11–13)	15 (10–19)	12 (11–13)	9 (7–10)	13 (11–15)	9 (8–10)	9 (8–9)	19	−1 (−2 to 0)	**0.035**	0.21
Functional performance, no. of hops												
One-leg long box jump (0–5)												
Dominant	411	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4	0 (0–0)	1.000	0.00
Non-dominant	414	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	4 (4–4)	15	0 (0–0)	0.570	0.06
Square hop test (15 s)												
Dominant	412	18 (17–18)	17 (16–17)	18 (17–18)	18 (17–19)	18 (17–19)	17 (16–18)	19 (19–20)	17	2 (2–3)	**<0.001**	0.71
Non-dominant	411	17 (16–17)	16 (15–17)	17 (16–17)	17 (16–18)	17 (16–18)	15 (15–16)	19 (18–20)	35	4 (3–4)	**<0.001**	0.99

Values are reported as max value of 3 repetitions. *p* values in bold type are significant. Effect size measured as Cohen's *d*, where *d* = 0.2 indicates a small effect, *d* = 0.5 indicates a medium effect, and *d* = 0.8 indicates a large effect. CI, confidence interval.
[a] Missing value from 0 to 3 players in the different tests both at baseline and at follow-up.

in a cohort of high school students aged 13–19 years who played basketball, football, lacrosse, or football (Onate et al., 2018). This highlights the importance of being specific when reporting normative values regarding measuring performance, sex, age, and sport.

To our knowledge, our study is the first to report normative data for trunk rotation tests. The tests have been used to identify risk factors or the relationship between a shoulder injury and trunk rotation flexibility in collegiate softball players (Aragon, Oyama, Oliaro, Padua, & Myers, 2012) and adolescent elite handball players (Asker et al., 2017), but no normative values have been reported.

4.2. Normative strength data

Normative data have been presented previously for strength around the hip and knee measured with a hand-held dynamometer (Daloia et al., 2018; Thorborg et al., 2013). In one study, results for

Table 6
Results from the tests for lower limb strength normalized to body weight and reported in Newton/kg body weight.

Strength tests	Total cohort		Total cohort divided into age groups				Sub-cohort[a]		Change in sub-cohort			
	12–17 years (N = 418)		12 years (n = 97)	13 years (n = 157)	14 years (n = 91)	15–17 years (n = 73)	12–17 years (n = 106)		Follow-up − baseline (n = 106)			
	N	Baseline (95% CI)	Baseline (95% CI)				Baseline (95% CI)	Follow-up (95% CI)	%	Mean (95% CI)	*p* value	Cohen's *d*
Trunk, isometric												
Wood chopper test, right	413	1.0 (1.0–1.1)	1.2 (1.2–1.3)	1.0 (1.0–1.1)	0.9 (0.8–1.0)	1.0 (0.9–1.1)	1.0 (1.0–1.1)	1.0 (1.0–1.1)	4	−0.1 (−0.5 to 0.1)	0.625	−0.05
Wood chopper test, left	413	1.1 (1.1–1.1)	1.1 (1.0–1.1)	1.2 (1.1–1.2)	1.0 (1.0–1.1)	1.0 (1.0–1.1)	1.0 (1.0–1.1)	1.1 (1.0–1.1)	7	0.0 (−0.1 to 0.1)	0.205	0.13
Hip, isometric												
Flexion												
Dominant	417	3.3 (3.2–3.4)	3.3 (3.1–3.5)	3.4 (3.3–3.6)	3.3 (3.1–3.5)	3.1 (2.8–3.3)	3.5 (3.3–3.7)	3.3 (3.2–3.5)	2	−0.2 (−0.3 to 0.0)	0.058	−0.19
Non-dominant	417	3.2 (3.1–3.3)	3.1 (2.9–3.3)	3.4 (3.2–3.5)	3.1 (2.9–3.3)	2.9 (2.7–3.1)	3.2 (3.0–3.4)	3.2 (3.1–3.4)	9	0.0 (−0.2 to 0.2)	0.809	0.02
Extension												
Dominant	414	2.5 (2.4–2.6)	2.4 (2.3–2.5)	2.6 (2.5–2.7)	2.5 (2.4–2.7)	2.4 (2.3–2.6)	2.5 (2.4–2.6)	2.7 (2.6–2.8)	15	0.2 (0.1–0.33)	**<0.001**	0.37
Non-dominant	416	2.4 (2.3–2.4)	2.3 (2.2–2.4)	2.4 (2.3–2.5)	2.5 (2.3–2.6)	2.3 (2.2–2.4)	2.4 (2.3–2.5)	2.6 (2.5–2.7)	12	0.2 (0.1–0.3)	**<0.001**	0.35
Adduction												
Dominant	415	1.6 (1.5–1.6)	1.7 (1.6–1.8)	1.4 (1.3–1.5)	1.7 (1.6–1.8)	1.6 (1.6–1.7)	1.8 (1.7–1.9)	1.8 (1.7–1.8)	3	−0.0 (−0.1 to 0.1)	0.889	−0.01
Non-dominant	416	1.6 (1.5–1.6)	1.6 (1.5–1.7)	1.4 (1.3–1.5)	1.7 (1.6–1.8)	1.6 (1.5–1.7)	1.7 (1.7–1.8)	1.7 (1.6–1.8)	2	−0.0 (−0.1 to 0.1)	0.487	−0.07
Abduction												
Dominant	416	1.6 (1.5–1.6)	1.6 (1.5–1.7)	1.4 (1.3–1.5)	1.7 (1.6–1.8)	1.6 (1.5–1.7)	1.6 (1.6–1.7)	1.8 (1.7–1.8)	13	0.1 (0.1–0.2)	**<0.001**	0.34
Non-dominant	415	1.5 (1.4–1.6)	1.6 (1.5–1.7)	1.4 (1.2–1.5)	1.6 (1.5–1.7)	1.6 (1.5–1.6)	1.6 (1.5–1.7)	1.7 (1.7–1.8)	14	0.2 (0.1–0.2)	**<0.001**	0.43
Hip, eccentric												
Adduction												
Dominant	414	2.1 (2.0–2.1)	2.1 (1.9–2.2)	1.8 (1.7–2.0)	2.3 (2.2–2.5)	2.2 (2.1–2.3)	2.4 (2.3–2.5)	2.4 (2.3–2.5)	5	0.0 (−0.1 to 0.1)	0.377	0.09
Non-dominant	415	2.0 (1.9–2.0)	1.9 (1.8–2.1)	1.7 (1.6–1.8)	2.3 (2.2–2.4)	2.1 (2.0–2.2)	2.3 (2.2–2.4)	2.4 (2.3–2.5)	6	0.1 (.0.0 to 0.2)	0.145	0.15
Abduction												
Dominant	416	1.8 (1.7–1.8)	1.7 (1.6–1.8)	1.5 (1.4–1.7)	2.1 (2.0–2.1)	1.9 (1.8–2.0)	2.0 (1.9–2.1)	2.2 (2.1–2.3)	15	0.2 (0.1–0.3)	**<0.001**	0.55
Non-dominant	415	1.8 (1.7–1.8)	1.8 (1.7–1.9)	1.5 (1.4–1.7)	2.0 (1.9–2.1)	1.9 (1.8–2.0)	1.9 (1.8–2.0)	2.2 (2.1–2.2)	16	0.3 (0.2–0.3)	**<0.001**	0.76
Knee, isometric												
Extension												
Dominant	417	4.4 (4.3–4.5)	4.5 (4.2–4.7)	4.6 (4.4–4.7)	4.2 (3.9–4.4)	4.1 (3.8–4.4)	4.2 (4.0–4.6)	4.4 (4.2–4.7)	14	0.2 (−0.0 to 0.4)	0.107	0.16
Non-dominant	417	4.2 (4.1–4.3)	4.2 (4.0–4.5)	4.3 (4.2–4.5)	4.0 (3.8–4.3)	3.9 (3.7–4.2)	4.0 (3.7–4.2)	4.3 (4.1–4.5)	18	0.3 (0.1–0.5)	**0.004**	0.29

Values are reported as max value of 3 repetitions. *p* values in bold type are significant. Effect size measured as Cohen's *d*, where $d = 0.2$ indicates a small effect, $d = 0.5$ indicates a medium effect, and $d = 0.8$ indicates a large effect. CI, confidence interval.
[a] Missing value from 0 to 2 players in the different tests both at baseline and at follow-up.

knee extension strength were similar to our results (Daloia et al., 2018). In our cohort, older players were generally stronger, especially for the hip muscles and knee extensors, but normalized to body weight this difference disappeared. Strength has been previously reported to be related to both age and body mass (Harbo et al., 2012). Using a hand-held dynamometer for isometric hip and knee strength measurements has been reported previously to be suitable for evaluating and monitoring athletes with hip, groin, and hamstring injuries, which are common injuries in football (Thorborg et al., 2013). Our results indicate that it is important to consider age, but also body weight, in future evaluations of hip and knee strength in young female football cohorts.

Normative data for the Biering-Sörensen test have been reported previously in woman of different ages and varied between 142 and 220 s (Moreau et al., 2001). In girls aged 15–18 years, results for the Biering-Sörensen test ranged from 148 to 228 s (Dejanovic, Cambridge, & McGill, 2014) compared with a mean of 146 s in our 15- to 17-year-old players. One explanation for the values in the lower range in previous studies could be differences in age and low motivation to identify perceived limit of fatigue in our players. An increase in endurance strength is expected with rapid growth during puberty and in our cohort, strength increased with age but was not correlated to body mass. Psychological outcome measures for motivation and perceived effort during isometric low back testing should also be evaluated further (Moreau et al., 2001). Extensor muscle endurance of the back seems to play an important role in prevention, rehabilitation and the risk of future back pain, and the Biering-Sörensen test might be of value as a screening tool for preventive measures (Moreau et al., 2001). Thus, it is important that clinicians have appropriate normative data to use, especially when baseline assessments are unavailable or inappropriate due to long test–retest intervals (Merritt et al., 2017).

4.3. Normative data of functional performance

The functional tests used, the OLLBJ and the square hop tests, are rarely described in the literature and we did not find any previous normative values for these tests. The single-leg hop for distance is more commonly used for evaluating hop performance (W. T. Davies, Myer, & Read, 2020). Our aim was to evaluate both hop performance and the ability to land and stop in a pre-specified area using one test. The OLLBJ is a modified single-leg hop-and-hold (van Melick et al., 2020) and takes the height of the player into account (G. J. Davies et al., 2017). However, most of the players achieved 4 out of 5 valid hops for OLLBJ. Thus, the test was probably too easy, and the players almost reached a ceiling effect. The square hop test includes multi-directional movements, which are characteristic for football, but this test is also described and performed in different ways (Caffrey et al., 2009; Gustavsson et al., 2006). In our study, the players jumped for 15 s in a square of 40 cm. Before the start of the study, a pilot study of the square hop test was performed. In this pilot, 65 players performed the test for 30 s, but players lost concentration and function so the test was changed to 15 s. Therefore, the best functional hop test to assess the player's unilateral jump performance for this cohort should be described and evaluated further.

4.4. Change in test results over 1 year

A sub-cohort was followed for 1 year and performed all the tests once more to analyse potential within-player changes. The sub-cohort had less ROM at baseline, especially in external and internal hip rotation, compared with the total cohort. The reason is unclear, but could be due to systematic measurement differences because the sub-cohort comprised the first 106 players included in the study. There were small increases in almost all ROM tests, but most of them probably had no clinical importance (Bullock et al., 2021) and below the MDC. ROM is reported to decrease with age (McKay et al., 2017), but apparently follow-up for a longer period than 1 year seems to be needed in this age group. A decreasing trend in ROM for almost all measurements in the hip with older age is reported, but this decline was less apparent among girls (Sankar et al., 2012).

The change in the test value reported as a percentage will help the clinician to interpret the results together with the ES. However, change in the percentage should be interpreted with caution for tests with low values (e.g. OLLBJ and heel raises), because a small change will result in a big percentage change. The strength in both the dominant and non-dominant legs increased in the knee extension (22%–26%) and in all directions in the hip (9%–24%), which could be a clinically important increase in strength. However, normalized to body weight, the increase was smaller and as the highest percentage change in hip abduction (13%–14%). The increase in strength was below the MDC. ES indicated mostly small to medium effects. Moreover, the large MDC could be explained in some cases by the wide range of performance and thus a wide range in SD in the test values among the players. Puberty with physical, psychical and social maturity could affect the strength tests results and the normative values for strength were also generally higher with older age. At the end of puberty, the girls are expected to develop increased strength due to increased height and body mass. This is important to bear in mind with the knowledge of rapid growth and maturation of our studied population, Therefore, we also presented strength values normalized to body weight. The participants' understanding of the importance of the tests and motivation could also affect the test results. Factors such as learning effects of the tests would not be relevant because of the time interval between the tests (1 year).

4.5. Strengths and limitations

We included a large, homogeneous cohort of young female competitive football players, which enabled analyses stratified by sex and sports. We used a longitudinal design to assess changes within individual players over a football season. The purpose was to report on young competitive female football players in general. Therefore, the players were tested at different time points during the season to avoid seasonal variations. We did not exclude players with injuries, but players were informed to refrain from certain tests that evoked pain, provoked ongoing injuries or other health-related issues. Clinical tests measuring ROM, strength, and functional performance that are simple, quick, low cost, and can be used by sports medicine clinicians in the field were used. However, simple and quick measurement techniques could also be associated with potential sources of error. The assessments included several challenges such as fixation of surrounding joint and tissues, standardizing the starting position, standardized instructions, isolated movements, goniometer/inclinometer/hand-held dynamometer placement, and rater dependence. Several different test leaders performed the measurements, which could be a weakness, but also a strength, because it reflects reality in the clinic. However, the measurements were also tested for intrarater, interrater reliability and MDC. Most of the tests had good or excellent intrarater and interrater reliability with ICC values > 0.75, indicating that the methods were reliable.

5. Conclusions

The present study provides clinicians and coaches with reference normative values to be used in the evaluation of ROM, strength and functional performance in adolescent female football players. The ROM and strength measurements normalized to body weight did not differ between the age groups. The test results changed slightly over 1 year with improvements especially in hip abduction strength and in the square hop test.

Ethical approval

The work has been approved by the Swedish Ethical Review Authority (Dnr 2016/1251-31/4). The participants gave informed consent to the work.

Data sharing

De-identified data are available from the first author upon reasonable request.

Funding

This study was funded by grants from the Swedish Research Council for Sport Science (P2019-0045, P2020-0100, P2022-0074), the Swedish Naprapathic Association, the Norwegian Naprapathic Association, Active life foundation and Sophiahemmet foundation.

Declaration of competing interest

None declare. The authors affirm that they have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

Ethics

The work has been approved by the Swedish Ethical Review Authority (Dnr 2016/1251-31/4).

All players and their parents or legal guardians (players under the age of 15 years) received oral and written information about the study and signed written consent.

Declaration of competing interest

The authors affirm that they have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

Acknowledgements

The authors acknowledge the participating players and coaches for their valuable contribution to the study. Our grateful thanks also to participating students at Scandinavian College of Naprapathic Manual Medicine, Stockholm, Sweden for your contribution.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2022.10.003.

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