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Motor skills of U15 category soccer players playing in different positions on the field

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Abstract

Study aim: The aim of the study was to evaluate the differences in strength and jumping abilities of adolescent soccer players playing in different positions on the field.
Material and methods: The study included 41 adolescent (14.53 ± 0.68 years old) soccer players: 6 goalkeepers (GK), 13 defenders (DF), 15 midfielders (MD) and 7 strikers (ST). We measured peak torques (PT), total work (TW), and average power (AP) developed by the knee flexors and extensors under isokinetic conditions at angular velocities of $300°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $60°\cdot s^{-1}$ on a Biodex dynamometer, as well as jump height (h), jump depth (d) and power (P_{max}) on a force plate.
Results: There was a statistically significant difference in body height between GK (181.17 ± 10.40 cm) and MD (165.60 ± 9.07 cm). PT, AP, TW, h, and P_{max} showed no statistically significant differences between the positions on the field. Significant correlations between jumping height and isokinetic measurements of the quadriceps were found in MD ($p < 0.05$). Correlations between jump power and isokinetic measurements of the quadriceps were found in all types of jumps in the DF and MD groups, whereas no correlation in the bounce counter-movement jump was shown by GK and ST ($p > 0.05$). MD showed an inverse relationship between the PT, AP, and TW at movement velocities of $300°\cdot s^{-1}$ and $180°\cdot s^{-1}$, and the jump depth in the akimbo counter-movement jump and counter-movement jump.
Conclusion: The observed differences in correlations between the positions are likely due to the different tasks assigned to the specific position during the match.

Keywords: Isokinetic – Jump – Football – Power – Strength

Introduction

Soccer is becoming more dynamic every year. Currently, soccer players playing in different positions on the field perform a greater number of high-intensity runs (19.8–25.1 $km\cdot h^{-1}$) and sprints (>25.1 $km\cdot h^{-1}$) during a match than in previous years, with the total distance covered changing insignificantly (Bush et al., 2015) . Therefore, in soccer, players should exhibit a high level of motor skills, mainly strength, which shows a correlation with running speed and jumping ability (Wisløff et al., 2004). The dominant role during jumps and kicks is fulfilled by a set of muscles that extend the knee (Lehance et al., 2009). During soccer-specific activities, knee flexors very often work eccentrically during the deceleration of rapid extension, performing the function of motion control and stabilization of the knee joint (Ruas et al., 2015).

During intensive sports training, the musculoskeletal system is exposed to high mechanical loads. The knee joint and thigh muscles of soccer players are among the most vulnerable to strain and injury (López-Valenciano et al., 2020) Failure to properly develop and increase the strength of the knee flexors and extensors can contribute to injuries to this joint. It is assumed that in isokinetic examinations, the ratio of the strength of the hamstrings to the strength of the quadriceps should be equal to or greater than the value of 0.6 (Kim & Hong, 2011). High levels of

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strength in the knee flexors can help prevent knee injuries (Yamaner et al., 2011).

The high level of developed strength and power of the lower limb muscles becomes crucial in achieving athletic success during soccer play. Therefore, regular monitoring of these motor characteristics is justified.

Soccer players should have an adequate level of motor skills and versatility. Players occupying different positions and performing various tasks during the game may differ from each other. Goalkeepers tend to be characterized by greater height and body mass compared to players who play in other positions on the field (Sutton et al., 2009). Side midfielders are generally faster than players in other positions, whereas side defenders show higher levels of agility (Bujanovsky et al., 2019). However, the results of studies of adult soccer players on the strength potential developed under isokinetic conditions appear to be inconsistent. According to Gouveia et al. (2023), the position a player plays does not significantly differentiate the isokinetic parameters of soccer players. Furthermore, in a study by Ruas et al. (2015), goalkeepers had stronger quadriceps in the absolute sense compared to players in other positions on the field.

In addition to the position of the player, the biomechanical parameters are also affected by age. Adult athletes show significantly better jumping height, static strength, and mean isokinetic power compared to younger athletes (França et al., 2023). Furthermore, the value of biomechanical indicators can change with the sports skill level of a player (Rebelo et al., 2013).

Most of the above-mentioned studies involve research on adult athletes, with the average age being over 18 years old (Bujanovsky et al., 2019; Gouveia et al., 2023; Ruas et al., 2015). Studies of young soccer players playing in different positions on the field are also inconsistent (Bona et al., 2017; Bonetti et al., 2017), reporting no significant differences in isokinetic strength, while in the study by Herdy goalkeepers developed higher values of muscle torques at $300°\cdot s^{-1}$, $180°\cdot s^{-1}$, and $60°\cdot s^{-1}$ compared to other players (Hauge Engebretsen et al., 2010). Given the lack of consensus among researchers in the field of teenage soccer players, it seems reasonable to undertake research in this area.

The aim of the study was to evaluate the differences in strength and jumping abilities of adolescent soccer players playing in different positions on the field.

The dynamic development of the football discipline can lead to changes in the motor preparation of young players and the emergence of specialization at an early stage. Therefore, we adopted and tested the hypothesis that there are differences in jumping abilities and strength potential among young football players.

Material and methods

This is a prospective, cross-sectional study with purposive sampling. The study involved 41 adolescent soccer players of the U15 category from three of the top soccer clubs in Poland. The eligibility criteria for participation in the study were the possession of a medical certificate of no contraindications to sports, and the absence of any injury in the 3 months preceding the study. The group of players was divided according to the position in which they played on the field: 6 goalkeepers, 13 defenders, 15 midfielders, and 7 strikers. The age of the subjects and the training experience were 14.53 ± 0.68 and 6.00 ± 1.26 years, respectively, in goalkeepers, 14.2 ± 0.4 and 6.00 ± 1.53 years in defenders, 14.41 ± 0.56 and 6.73 ± 0.96 years in midfielders, and 14.58 ± 0.26 and 6.57 ± 0.53 years in strikers. The study was approved by the Bioethics Committee of the Institute of Sport – National Research Institute (approval number: KEBN-16-19-AP). Written informed consent was obtained from the participants and their legal guardians. The study was conducted according to the Declaration of Helsinki.

The anthropometric indices of the study group are presented in Table 1. The players from different positions on the field did not differ significantly in age or training experience.

Analysis of variance indicated the presence of a statistically significant difference between groups of players playing in different positions relative to body mass ($F_{3,37} = 3.81$; $p < 0.05$).

Table 1. Characteristics of the U15 soccer players playing in different positions on the field (mean±SD and 95% CI)

	All team (n = 41)	GK (n = 6)	DEF (n = 13)	MID (n = 15)	ST (n = 7)	F	p	η^2
Body height [cm]	171.49 ± 10.45 (168.19 ÷ 174.79)	181.17 ± 10.40 (170.25 ÷ 192.08)	170.62 ± 8.89 (165.24 ÷ 175.99)	165.60 ± 9.07 * (160.58 ÷ 170.62)	177.43 ± 8.04 (169.99 ÷ 184.86)	5.45	0.003	0.31
Body mass [kg]	59.03 ± 11.66 (55.35 ÷ 62.71)	67.55 ± 14.66 (52.16 ÷ 82.94)	57.55 ± 9.66 (51.71 ÷ 63.38)	53.53 ± 8.69 (48.72 ÷ 58.35)	66.24 ± 12.26 (54.90 ÷ 77.58)	3.81	0.018	0.24

Legend: GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, F – value of F-statistic, p – probability, η^2 – value of effect size, * – statistically significantly different to goalkeepers

However, the post hoc analysis showed no statistically significant differences. There was a statistically significant difference in body height between goalkeepers and players playing in the midfielder position ($p<0.05$).

Measurement protocol

Upon arrival at the laboratory, the players were instructed on the purpose, the experimental procedure, and the possibility of withdrawal from the measurements at any time during the tests. Written consent forms, signed by players and their legal guardians, were collected for the participation of adolescent players in the study. Anthropometric measurements were then taken. Body height was measured with a SiberHegner anthropometer (Switzerland), and body mass was measured using a Tanita TBF 300 body composition analyzer (Japan). Next, the players proceeded to individual warm-ups. After the player was ready, the isokinetic measurements were performed, followed by jumping tests.

Isokinetic measurement

The Biodex System 4 Pro isokinetic dynamometer was used to evaluate the values of muscle torques of the right and left knee joints under isokinetic conditions. The device was equipped with a software-controlled dynamometer to allow constant external conditions for muscle work. System Advantage 4 Software, version 4.63, was used in every test. The player sat in a seat with the backrest tilted 15º from the vertical line and was stabilized by three straps attached to the plane of the backrest. In addition, the player's thigh was immobilized relative to the seat with a single strap. The mobility of the seat and dynamometer head allowed for accurate positioning of the knee and hip joint axes relative to the axis of rotation of the dynamometer lever. Testing was performed in the sagittal plane. The hip girdle and torso were stabilized with special straps. The players were instructed to make three movements on hearing a command from the test supervisor, each of extension and flexion at the knee joint while moving the dynamometer lever as much as they could throughout the range of motion. In the study, we focused on measuring the ability to develop strength under dynamic conditions. The players performed the measurements at the movement velocities of $60°\cdot s^{-1}$, $180°\cdot s^{-1}$, and $300°\cdot s^{-1}$, to assess strength potential at low, medium and high speeds, respectively. The largest recorded value of the muscle torque (in newton-meters) developed at each velocity was selected. In further analysis, the average values obtained from measurements separately for the right and left lower limbs were used.

Jumping measurement

The power output of lower extremities and the height of the rise of the body mass center (COM) during vertical jumps were measured using a force plate ("JBA" Zb. Staniak, Poland). The MVJ v. 3.4 software package ("JBA" Zb. Staniak, Poland) was used for measurements. Parameters below were calculated from the recorded ground reaction force:

- absolute peak power (P_{max}) – peak value from the course of changes in the power (in Watts) value developed during rebound,
- mean power (P_{mean}) – the average value from the course of changes in the value of power (in Watts) developed during the rebound (in the concentric muscle contraction phase),
- maximum height of rise of the body's COM (h) – maximum value of displacement values (in centimeters) calculated by double integration of the course of changes in acceleration values,
- countermovement depth (d) – minimum value of displacement (in centimeters) values calculated by double integration of the course of changes in acceleration values.

Each participant performed nine vertical jumps on the force plate: three jumps of each kind. The characteristics of each jumping test were as follows:

ACMJ – akimbo counter-movement jump – a vertical jump from an upright standing position with hands on the hips and counter-movement of the COM before the take-off;

CMJ – counter-movement jump – a vertical jump from a standing erect position, preceded by an arm-swing and counter-movement of the body COM before the take-off;

BCMJ – bounce counter-movement jump – a vertical jump measured after the tested player jumps on a platform from a several-meter run-up with an arm-swing and counter-movement of the body COM before the take-off.

It was assumed that each of the jumps would represent a slightly different movement task, with varying degrees of complexity. The use of three different types of jumps will further provide a picture of the coordination abilities of young athletes. The analysis included an average of three jumps, from each type. The research methodology adopted is a continuation of our previous work; for details see: (Gajewski et al., 2018; Górski et al., 2019).

Statistical analysis

Descriptive statistical analysis consisted in the determination of mean values (M), standard deviations (SD) and 95% confidence intervals (CI) of the mean indices studied. The normality of the distribution of variables was verified using the Shapiro-Wilk test.

We used the Levene test and the Mauchly test to evaluate homogeneity and sphericity of variance, respectively. One-way analysis of variance (ANOVA) was used to evaluate differences in anthropological indices (see Table 1). A repeated-measures two-way analysis of variance (ANOVA) was used to analyze differences in indices characterizing isokinetic strength and performance in the jumping tests. The effect size was assessed using partial η^2, classified as small ($0.01 < \eta^2 \leq 0.06$), medium ($0.06 < \eta^2 \leq 0.14$), and large ($\eta^2 > 0.14$) (Cohen, 1988). If the assumption of sphericity of variance was not met, the Greenhouse-Geisser correction was employed to adjust the probability value p. Differences between groups were compared using the post hoc Tukey's test with correction for different group sizes. If the assumption of homogeneity of variance was not met, the Dunnett test was additionally applied. Pearson's linear correlation coefficient was used to analyze the relationship between the variables. The strength of the relationship was assessed as small ($R < 0.1$), medium ($0.1 < R \leq 0.5$), or large ($R > 0.5$) (Cohen, 2013). The level of significance for the above analyses was set at $p = 0.05$. Statistical analysis was conducted using the STATISTICA v. 13.1 (TIBCO Software Inc., 2017) and Microsoft Excel 2016 software (Microsoft Corporation, 2016).

Results

Table 2 contains the results of the jumping test. In the analysis of jump height (h), swing depth (d), and peak and mean power (P_{max} and P_{mean}, respectively), there was no statistically significant effect to indicate differences in the groups due to the player's position on the field. A differential effect of the analyzed indices by the type of jump was observed.

Table 2. Jump height, swing depth, and maximum and mean relative power developed during vertical jumps

	Jump type	GK (n = 6)	DEF (n = 13)	MID (n = 15)	ST (n = 7)	Interaction	F	p	η^2
h [cm]	ACMJ	33.57 ± 4.28 (29.08 ÷ 38.07)	32.39 ± 3.86 (30.05 ÷ 34.72)	31.35 ± 3.32 (29.51 ÷ 33.19)	32.49 ± 1.99 (30.65 ÷ 34.32)	Position	1.47	0.239	0.11
	CMJ	40.56 ± 6.44 (33.8 ÷ 47.32)	39.59 ± 3.88 (37.25 ÷ 41.94)	36.25 ± 3.94 (34.07 ÷ 38.43)	38.44 ± 2.36 (36.26 ÷ 40.63)	Jump Type	351	<0.001	0.90
	BCMJ	47.84 ± 9.41 (37.97 ÷ 57.71)	46.31 ± 3.65 (44.11 ÷ 48.52)	43.6 ± 4.82 (40.94 ÷ 46.27)	45 ± 3.37 (41.88 ÷ 48.11)	Position x Jump type	0.97	0.435	0.07
d [cm]	ACMJ	37.16 ± 8.08 (45.64 ÷ 28.67)	33.84 ± 6.39 (37.7 ÷ 29.97)	34.41 ± 6.53 (38.03 ÷ 30.8)	29.35 ± 2.12 (31.31 ÷ 27.39)	Position	1.85	0.155	0.13
	CMJ	39.07 ± 8.03 (47.49 ÷ 30.65)	36.59 ± 6.44 (40.48 ÷ 32.7)	34.19 ± 4.23 (36.55 ÷ 31.87)	33.56 ± 4.60 (37.81 ÷ 29.30)	Jump Type	25	<0.001	0.40
	BCMJ	32.23 ± 7.54 (40.15 ÷ 24.32)	30.31 ± 2.96 (32.11 ÷ 28.52)	27.45 ± 4.83 (30.13 ÷ 24.77)	28.18 ± 6.42 (34.11 ÷ 22.24)	Position x Jump type	1.16	0.338	0.09
P_{max} [W]	ACMJ	1452 ± 436 (995 ÷ 1909)	1296 ± 429 (1037 ÷ 1556)	1092 ± 245 (957 ÷ 1227)	1611 ± 314 (1320 ÷ 1902)	Position	2.83	0.052	0.19
	CMJ	1980 ± 601 (1349 ÷ 2610)	1767 ± 481 (1476 ÷ 2057)	1540 ± 419 (1308 ÷ 1773)	2046 ± 231 (1833 ÷ 2260)	Jump Type	181	<0.001	0.83
	BCMJ	3035 ± 1030 (1954 ÷ 4116)	2512 ± 681 (2101 ÷ 2924)	2476 ± 677 (2101 ÷ 2851)	3094 ± 641 (2501 ÷ 3686)	Position x Jump type	0.73	0.581	0.06
P_{mean} [W]	ACMJ	843 ± 280 (550 ÷ 1137)	736 ± 269 (574 ÷ 899)	632 ± 149 (550 ÷ 715)	955 ± 238 (735 ÷ 1176)	Position	2.60	0.066	0.17
	CMJ	975 ± 266 (697 ÷ 1254)	866 ± 314 (676 ÷ 1055)	743 ± 185 (641 ÷ 845)	977 ± 181 (810 ÷ 1144)	Jump Type	159	<0.001	0.81
	BCMJ	1687 ± 535 (1125 ÷ 2248)	1437 ± 438 (1172 ÷ 1702)	1415 ± 380 (1204 ÷ 1625)	1772 ± 413 (1391 ÷ 2154)	Position x Jump type	0.57	0.686	0.04

Legend: h – jump height, d – countermovement depth, P_{max} – jump absolute peak power, P_{mean} – jump mean power, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, ACMJ – akimbo counter-movement jump, CMJ – counter-movement jump, BCMJ – bounce counter-movement jump.

The studied players, performing successive jumping tests, obtained significantly different values of the elevation of the center of mass ($F_{2,74} = 351$; $p < 0.05$) and peak power ($F_{2,74} = 181$; $p < 0.05$) in all jumps. BCMJ, performed by all the athletes studied, differed significantly in swing depth ($F_{2,74} = 25$; $p < 0.05$) and mean power ($F_{2,74} = 159$; $p < 0.05$) from ACMJ and CMJ. There were no differences in these indices between ACMJ and CMJ ($p > 0.05$). For all the statistically significant differences noted, the effect size values were rated as large. There was no statistically significant interaction between the type of jump and the position in which the players played.

Table 3 shows the results of measurements of peak torques (PT), total work (TW), and average power (AP) developed under isokinetic contraction. The indices studied, which characterize the muscle groups of the knee extensors and flexors, were not significantly different between the playing positions on the field. Analysis of variance indicated the presence of statistically significant differences between groups of individuals playing in different positions in terms of muscle peak torque ($F_{3,37} = 3.86$; $p < 0.05$) and average power of the knee extensors ($F_{3,37} = 2.90$; $p < 0.05$). However, the post hoc analysis showed no statistically significant differences between groups.

Table 3. Maximum values of peak torque, total work, and average power developed during isokinetic tests

	Angular Velocity [°·s^{-1}]	GK (n = 6)	DEF (n = 13)	MID (n = 15)	ST (n =7)	Interaction	F	p	η²
QPT [Nm]	300	96 ± 26 (68 ÷ 124)	86 ± 16 (76 ÷ 96)	76 ± 19 (66 ÷ 87)	102 ± 16 (87 ÷ 116)	Position	3.86	0.017	0.24
	180	130 ± 34 (94 ÷ 165)	116 ± 24 (101 ÷ 131)	102 ± 25 (88 ÷ 116)	134 ± 20 (115 ÷ 153)	Angular Velocity	364	<0.001	0.91
	60	189 ± 56 (131 ÷ 247)	158 ± 35 (137 ÷ 180)	138 ± 29 (121 ÷ 154)	181 ± 28 (155 ÷ 207)	Position x Angular Velocity	2.95	0.034	0.19
HPT [Nm]	300	57 ± 17 (39 ÷ 74)	52 ± 10 (46 ÷ 58)	52 ± 13 (45 ÷ 59)	66 ± 5 (61 ÷ 71)	Position	2.77	0.055	0.18
	180	68 ± 20 (46 ÷ 89)	65 ± 14 (56 ÷ 73)	63 ± 17 (53 ÷ 72)	77 ± 13 (65 ÷ 89)	Angular Velocity	148	<0.001	0.80
	60	109 ± 40 (67 ÷ 150)	84 ± 20 (72 ÷ 96)	80 ± 21 (68 ÷ 91)	107 ± 18 (90 ÷ 123)	Position x Angular Velocity	3.62	0.011	0.23
QAP [W]	300	227 ± 82 (141 ÷ 313)	221 ± 44 (194 ÷ 247)	199 ± 69 (161 ÷ 237)	273 ± 51 (226 ÷ 320)	Position	2.90	0.048	0.19
	180	232 ± 63 (167 ÷ 298)	212 ± 47 (183 ÷ 240)	185 ± 57 (153 ÷ 217)	250 ± 40 (213 ÷ 287)	Angular Velocity	221	<0.001	0.86
	60	121 ± 35 (84 ÷ 158)	104 ± 23 (90 ÷ 118)	91 ± 23 (78 ÷ 104)	120 ± 18 (103 ÷ 136)	Position x Angular Velocity	1.56	0.187	0.11
HAP [W]	300	85 ± 54 (28 ÷ 142)	101 ± 32 (81 ÷ 120)	99 ± 51 (71 ÷ 127)	132 ± 35 (99 ÷ 164)	Position	1.82	0.161	0.13
	180	113 ± 50 (61 ÷ 165)	115 ± 30 (97 ÷ 133)	108 ± 35 (89 ÷ 128)	144 ± 24 (122 ÷ 166)	Angular Velocity	70	<0.001	0.65
	60	68 ± 28 (38 ÷ 97)	58 ± 16 (48 ÷ 67)	55 ± 15 (47 ÷ 63)	75 ± 10 (66 ÷ 84)	Position x Angular Velocity	1.14	0.350	0.08
QTW [J]	300	294 ± 109 (180 ÷ 408)	287 ± 56 (253 ÷ 321)	277 ± 101 (221 ÷ 333)	363 ± 69 (299 ÷ 427)	Position	1.99	0.133	0.14
	180	413 ± 125 (281 ÷ 544)	390 ± 91 (334 ÷ 445)	366 ± 106 (307 ÷ 425)	473 ± 70 (408 ÷ 538)	Angular Velocity	220	<0.001	0.86
	60	497 ± 138 (353 ÷ 642)	483 ± 109 (417 ÷ 549)	426 ± 134 (352 ÷ 500)	562 ± 104 (466 ÷ 658)	Position x Angular Velocity	1.51	0.208	0.11
HTW [J]	300	123 ± 77 (42 ÷ 204)	149 ± 42 (124 ÷ 175)	153 ± 78 (110 ÷ 197)	193 ± 53 (144 ÷ 242)	Position	1.84	0.157	0.13
	180	212 ± 94 (113 ÷ 311)	237 ± 59 (201 ÷ 272)	233 ± 93 (182 ÷ 285)	298 ± 47 (255 ÷ 342)	Angular Velocity	173	<0.001	0.82
	60	325 ± 136 (182 ÷ 468)	293 ± 83 (243 ÷ 343)	274 ± 87 (226 ÷ 322)	386 ± 62 (328 ÷ 443)	Position x Angular Velocity	2.85	0.031	0.19

Legend: H – hamstrings, Q – quadriceps, PT – peak torque, AP – average power, TW – total work, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers

Isokinetic measurements at three different angular velocities showed that the athletes developed different values for peak torques and total work performed by the quadriceps ($F_{2,74} = 364$; $p < 0.05$ and $F_{2,74} = 220$; $p < 0.05$, respectively) and knee flexors ($F_{2,74} = 148$; $p < 0.05$ and $F_{2,74} = 173$; $p < 0.05$, respectively), and generated different average power of the knee flexors ($F_{2,74} = 70$; $p < 0.05$). There was a statistically significant difference between the average power of the quadriceps ($F_{2,90} = 221$; $p < 0.05$) developed only at velocities of 300°·s^{-1} and 60°·s^{-1} ($p < 0.05$) as well as between 180°·s^{-1} and 60°·s^{-1} ($p < 0.05$). The results of the analysis of variance indicated a statistically significant interaction between the velocity of movement and the position on the field for the peak torque of the knee extensors ($F_{6,74} = 2.95$; $p < 0.05$) and flexors ($F_{6,74} = 3.62$; $p < 0.05$) and the total work performed by the knee flexors ($F_{6,74} = 2.85$; $p < 0.05$). However, the post hoc analysis showed no statistically significant differences at a given velocity between players playing in different positions on the field. For all the statistically significant differences noted, the effect size values were rated as large.

Table 4 shows the values of the ratios of torques (PT H/Q ratio), total work (TW H/Q ratio), and average power (AP H/Q ratio) of the knee flexors and extensors in isokinetic conditions. There were no statistically significant differences among players playing in different positions on the field. The proportions of average power developed by the knee extensors and flexors differed significantly in movements at all three angular velocities (F2,74 = 46; $p < 0.05$). The ratio of torques and total work performed by antagonistic muscles differed significantly ($F_{2,74} = 14$; $p < 0.05$ and F2,74 = 38; $p < 0.05$, respectively) only between movements performed at speeds of 300°·s^{-1} and 180°·s^{-1}, and also between 300°·s^{-1} and 60°·s^{-1}. The effect sizes of the comparisons were large. There was no statistically significant interaction between the movement velocity and the position in which the players played.

Table 4. Ratios of peak torques (PT H/Q ratio), total work (TW H/Q ratio), and average power (AP H/Q ratio) of the knee flexors and extensors in isokinetic conditions

	Angular Velocity [°·s^{-1}]	GK (n = 6)	DEF (n = 13)	MID (n = 15)	ST (n = 7)	Interaction	F	p	η²
PT H/Q ratio [-]	300	0.61 ± 0.14 (0.46 ÷ 0.75)	0.61 ± 0.06 (0.57 ÷ 0.65)	0.69 ± 0.10 (0.64 ÷ 0.75)	0.66 ± 0.10 (0.57 ÷ 0.75)	Position	2.71	0.059	0.18
	180	0.52 ± 0.06 (0.46 ÷ 0.58)	0.56 ± 0.06 (0.52 ÷ 0.60)	0.62 ± 0.12 (0.55 ÷ 0.69)	0.58 ± 0.02 (0.55 ÷ 0.6)	Angular Velocity	14	<0.001	0.28
	60	0.57 ± 0.10 (0.46 ÷ 0.68)	0.53 ± 0.06 (0.49 ÷ 0.57)	0.58 ± 0.09 (0.53 ÷ 0.63)	0.59 ± 0.04 (0.55 ÷ 0.63)	Position x Angular Velocity	0.94	0.457	0.07
AP H/Q ratio [-]	300	0.35 ± 0.13 (0.21 ÷ 0.48)	0.45 ± 0.08 (0.40 ÷ 0.50)	0.48 ± 0.16 (0.40 ÷ 0.57)	0.48 ± 0.07 (0.41 ÷ 0.55)	Position	2.48	0.076	0.17
	180	0.47 ± 0.11 (0.35 ÷ 0.58)	0.54 ± 0.07 (0.5 ÷ 0.58)	0.56 ± 0.12 (0.50 ÷ 0.63)	0.58 ± 0.06 (0.52 ÷ 0.64)	Angular Velocity	46	<0.001	0.56
	60	0.55 ± 0.09 (0.45 ÷ 0.64)	0.55 ± 0.06 (0.51 ÷ 0.59)	0.61 ± 0.08 (0.56 ÷ 0.65)	0.63 ± 0.05 (0.58 ÷ 0.68)	Position x Angular Velocity	1.05	0.391	0.08
TW H/Q ratio [-]	300	0.39 ± 0.14 (0.24 ÷ 0.54)	0.52 ± 0.08 (0.47 ÷ 0.57)	0.54 ± 0.16 (0.45 ÷ 0.63)	0.53 ± 0.08 (0.45 ÷ 0.60)	Position	2.17	0.108	0.15
	180	0.50 ± 0.11 (0.38 ÷ 0.62)	0.61 ± 0.07 (0.56 ÷ 0.65)	0.63 ± 0.14 (0.56 ÷ 0.71)	0.63 ± 0.06 (0.57 ÷ 0.69)	Angular Velocity	38	<0.001	0.51
	60	0.63 ± 0.12 (0.51 ÷ 0.76)	0.60 ± 0.07 (0.56 ÷ 0.64)	0.65 ± 0.09 (0.60 ÷ 0.70)	0.69 ± 0.06 (0.63 ÷ 0.75)	Position x Angular Velocity	2.30	0.061	0.16

Legend: H – hamstrings, Q – quadriceps, PT – peak torque, AP – average power, TW – work, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers

Table 5 shows the values of Pearson's correlation coefficient characterizing the relationship between the height of vertical jumps and the results of isokinetic measurements for the quadriceps in players playing in different positions.

Table 5. Values of Pearson's correlation coefficient between vertical jump height and results of measurements for the quadriceps in isokinetic conditions

	Angular Velocity [$°\cdot s^{-1}$]	h [cm]											
		GK (n = 6)			DEF (n = 13)			MID (n = 15)			ST (n = 7)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
QPT [Nm]	300	0.58	0.62	0.37	0.42	0.42	0.11	0.65*	0.75*	0.63*	0.61	0.72	0.28
	180	0.71	0.76	0.52	0.44	0.43	0.25	0.68*	0.76*	0.62*	0.50	0.71	0.08
	60	0.73	0.82*	0.60	0.43	0.46	0.34	0.77*	0.74*	0.59*	0.45	0.68	0.02
QAP [W]	300	0.32	0.33	0.16	0.43	0.41	0.10	0.61*	0.71*	0.64*	0.68	0.76*	0.35
	180	0.78	0.82*	0.64	0.41	0.47	0.27	0.41	0.58*	0.58*	0.52	0.69	0.02
	60	0.75	0.84*	0.66	0.53	0.58*	0.40	0.70*	0.73*	0.57*	0.31	0.44	−0.34
QTW [J]	300	0.29	0.31	0.12	0.36	0.36	0.07	0.61*	0.72*	0.65*	0.64	0.85*	0.35
	180	0.62	0.71	0.48	0.27	0.36	0.17	0.66*	0.77*	0.66*	0.55	0.80*	0.11
	60	0.70	0.77	0.65	0.37	0.47	0.25	0.69*	0.77*	0.66*	0.51	0.76*	−0.02

Legend: GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, Q – quadriceps, PT – peak torque, AP – average power, TW – total work, h – jump height, ACMJ – akimbo counter-movement jump, CMJ – counter-movement jump, BCMJ – bounce counter-movement jump, * – statistically significant.

Midfielders were notable among the positions analyzed on the field. This was a group in which jump height was significantly correlated with the results of isokinetic measurements of the quadriceps ($p < 0.05$). The only exception was the lack of a relationship between the height of elevation of the center of body mass in the ACMJ jump and the average power developed at $180°\cdot s^{-1}$. Table 6 shows the values of Pearson's correlation coefficient characterizing the relationship between the absolute peak power developed during vertical jumps and the results of isokinetic measurements of the quadriceps in players playing in different positions.

Table 6. Values of Pearson's correlation coefficient between the peak power developed during jumping tests and the results of measurements of the quadriceps in isokinetic conditions

	Angular Velocity [$°\cdot s^{-1}$]	P_{max} [W]											
		GK (n = 6)			DEF (n = 13)			MID (n = 15)			ST (n = 7)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
QPT [Nm]	300	0.87*	0.77	0.36	0.58*	0.81*	0.65*	0.74*	0.85*	0.73*	0.88*	0.51	0.21
	180	0.95*	0.87*	0.47	0.69*	0.74*	0.80*	0.83*	0.84*	0.78*	0.92*	0.55	0.33
	60	0.91*	0.92*	0.52	0.54	0.57*	0.72*	0.84*	0.84*	0.81*	0.91*	0.51	0.29
QAP [W]	300	0.67	0.59	0.28	0.58*	0.79*	0.63*	0.67*	0.82*	0.72*	0.77*	0.56	0.38
	180	0.91*	0.93*	0.61	0.68*	0.71*	0.83*	0.54*	0.70*	0.59*	0.92*	0.64	0.43
	60	0.87*	0.95*	0.61	0.59*	0.66*	0.76*	0.76*	0.80*	0.73*	0.88*	0.81*	0.58
QTW [J]	300	0.67	0.57	0.24	0.59*	0.80*	0.65*	0.67*	0.82*	0.74*	0.69	0.51	0.38
	180	0.89*	0.88*	0.46	0.59*	0.68*	0.76*	0.77*	0.84*	0.78*	0.83*	0.61	0.47
	60	0.80	0.95*	0.68	0.54	0.55	0.70*	0.73*	0.82*	0.78*	0.81*	0.75	0.63

Legend: Q – quadriceps, PT – peak torque, AP – average power, TW – total work, P_{max} – absolute peak power, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, ACMJ – akimbo counter-movement jump, CMJ – counter-movement jump, BCMJ – bounce counter-movement jump, * – statistically significant.

In the group of players playing in the midfielder position, the peak power developed during vertical jumps correlated with all indices of the strength potential of the quadriceps obtained during isokinetic measurements.

Significant correlations were also noted for defenders. The exception was the lack of a significant relationship between the power developed in the ACMJ and the peak torque developed during movement at $60°·s^{-1}$, as well as in the total work during movement at $60°·s^{-1}$ and the peak power developed in the ACMJ and CMJ. In strikers, absolute peak power developed during ACMJ correlated significantly with all indices from isokinetic measurements except for the value of total work done at $300°·s^{-1}$. BCMJ did not correlate significantly with any of the isokinetic indices in the groups of goalkeepers and strikers ($p > 0.05$).

The strength of the relationship between the depth of the lowering of the body's center of gravity before the take-off and the strength capabilities of the knee flexors are shown in Table 7.

Table 7. Values of Pearson's correlation coefficient between the swing depth in vertical jumps and results of isokinetic measurements of the hamstrings

	Angular Velocity [°·s⁻¹]	d [cm]											
		GK (n = 6)			DEF (n = 13)			MID (n = 15)			ST (n = 7)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
HPT [Nm]	300	−0.04	−0.08	−0.39	−0.16	0.15	0.15	−0.72*	−0.66*	−0.34	−0.02	−0.63	−0.17
	180	−0.25	−0.47	−0.67	−0.08	−0.06	0.31	−0.60*	−0.52*	−0.19	−0.38	−0.74	−0.58
	60	−0.05	−0.53	−0.90*	−0.02	−0.11	0.18	−0.43	−0.36	−0.09	−0.10	−0.54	−0.50
HAP [W]	300	0.04	−0.10	−0.49	−0.10	0.39	0.34	−0.65*	−0.66*	−0.42	−0.43	−0.36	0.09
	180	−0.26	−0.33	−0.49	0.02	0.02	0.38	−0.58*	−0.53*	−0.25	−0.32	−0.58	−0.53
	60	−0.36	−0.47	−0.59	−0.13	−0.24	0.16	−0.32	−0.28	−0.03	−0.09	−0.24	−0.37
HTW [J]	300	0.06	−0.13	−0.53	−0.04	0.44	0.36	−0.64*	−0.65*	−0.39	−0.40	−0.38	0.09
	180	−0.25	−0.37	−0.56	0.09	0.07	0.38	−0.62*	−0.55*	−0.19	−0.43	−0.64	−0.50
	60	−0.20	−0.51	−0.79	−0.14	−0.27	0.14	−0.44	−0.40	−0.16	−0.44	−0.57	−0.51

Legend: H – hamstrings, PT – peak torque, AP – average power, TW – total work, d – countermovement depth, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, ACMJ – akimbo counter-movement jump, CMJ – counter-movement jump, BCMJ – bounce counter-movement jump, * – statistically significant.

A statistically significant inverse relationship between the values of torque, average power, and total work during isokinetic measurements at movement velocities of $300°·s^{-1}$ and $180°·s^{-1}$ and the depth of swing during ACMJ and CMJ was found in the midfielders.

Discussion

In our study, we placed emphasis on determining the differences between the motor capabilities of young football players playing in different positions on the field. Although we did not observe significant differences in isokinetic and jumping performance among young soccer players, it is worth noting that there were statistically significant differences in players' anthropometrics. We found a difference in body height. Goalkeepers were significantly taller compared to midfielders. Also noteworthy are the players playing in the midfielder position. They stood out from other players. In this group, we found a relationship between the swing depth and jump height in the jumping tests with isokinetic measurements.

Soccer players move on the field in a very dynamic manner during the game. With the increasing number of high-intensity sprints and runs (Bush et al., 2015), effective playing is determined by the ability to develop explosive muscle strength. There is a relationship between the rate of force (muscle torque) development and vertical jump height (Thompson et al., 2013) Among adolescent soccer players, running speed has been shown to be related to vertical jump height (Chuman et al., 2013), agility (Espada et al., 2020), and the ability to change direction quickly (Medeiros et al., 2023). Vertical jumps are also an activity repeatedly performed by soccer players in all positions on the field. In our study, the jump height did not differ significantly between players in different positions. These values are consistent with findings reported previously (Espada et al., 2020; Evangelidis et al., 2017; Forbes et al., 2009; França et al., 2023; Gajewski et al., 2018; Gil et al., 2010; Gouveia et al., 2023). In opposition are the results of a study by Portes et al. (2015), in which goalkeepers jumped the highest among all the players studied, and in other studies (Gil et al., 2010; Nikolaos et al., 2022), where a difference between strikers and midfielders was noted.

In contrast, the differences between players playing in different positions in our study were evident in the correlation of jump height and the values of peak torques developed by the quadriceps in isokinetic conditions. Of all the players, the adolescent midfielders stood out from other players on the field. The occurrence of this correlation only in midfielders may be related to the way they play during matches. The quadriceps muscles are heavily engaged when covering short distances at high speed, for which it is necessary to develop high force in a short time. Players playing in the midfielder position make the most moves at distances between 2 and 40 meters and sprints between 2–9 m and 30–40 m (Vigne et al., 2010). Players in different positions on the field are given different tasks to perform during the game. Performance of these tasks during the game may be related to the number of jumps, for which young players use their knee extensors to a different degree than players in other positions. This correlation may also stem from the coach's decision in assigning positions, with players in better physical condition being more likely to be chosen for the midfielder role (Daneshjoo et al., 2013; Lago-Peñas et al., 2014).

In our study, we also noted a relationship between the depth of the swing performed before the jump and the level of strength of the hamstrings in players playing in the midfielder position. A negative correlation mainly concerned isokinetic indices developed at high speeds, i.e. at angular velocities of $300°\cdot s^{-1}$ and $180°\cdot s^{-1}$. The lack of correlation at low velocities ($60°\cdot s^{-1}$) may be due to the physiological strength-speed capabilities of the hamstrings and lesser ability to develop force at low speeds (Evangelidis et al., 2017). This may be confirmed by the ratios of the strength capabilities of the hamstrings to the strength capabilities of the quadriceps (H/Q ratio). An increasing contribution of the strength of the hamstrings relative to the quadriceps in the ratio and an increasing value of the ratio with increasing movement velocity at which it was determined have been observed (Buśko et al., 2018; Daneshjoo et al., 2013; Lehance et al., 2009). During the kicking of a soccer ball, the knee flexors show the greatest activity in the following phases: preparation, backward swing, and deceleration of the limb after the kick (Cerrah et al., 2015). Therefore, during kicks, they perform control and stabilization functions of the knee joint, just as they do when lowering the body's center of gravity during vertical jumps.

In addition to body mass, body height and swing depth are predictors of the ability to develop peak power during vertical jumps (Gajewski et al., 2018). Table 6 shows the correlations between the peak power developed during the jumping tests and the results of isokinetic measurements of the quadriceps. No correlations were observed in BCMJ in goalkeepers and strikers. The BCMJ is preceded by a short run-up and the height of the BCMJ jump is a product of running skills, jumping ability, and coordination skills to utilize the speed achieved in the horizontal direction to develop speed in the vertical direction. Our study examined adolescent players. The lack of correlation may be due to the lower level of coordination in the players and their inability to realize their potential during jumps, or simply due to the small size of the groups. In goalkeepers, the power developed during ACMJ and CMJ correlated well with isokinetic test results, especially at movement speeds of $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$. Total work and power developed by strikers during isokinetic contraction showed a significant relationship with the power developed during ACMJ. In a study by Buśko et al. (2018) relationships were also found between the power generated by lower limb muscles during jumping tests and peak torques of the quadriceps at velocities of $60°\cdot s^{-1}$, $180°\cdot s^{-1}$, $300°\cdot s^{-1}$.

Jumping ability can be affected by the degree of sexual development. According to Wilczyński et al. (2022), athletes who started puberty earlier achieved better results in jumping tests. Chuman et al. (2013) reported that sexual transformation causes an increase in the size of the skeletal muscles of the lower limbs, leading to an increase in their strength and the power generated during jumps. Crewther documented a link between the height of vertical jumps and the male sex hormone testosterone, the blood concentration of which increases during adolescence. Furthermore, Crewther noted that the effects of testosterone on the physical fitness of young athletes may be moderated by other biochemical compounds (Crewther et al., 2022; Csáki et al., 2014). Different psychophysical characteristics caused by biological transformations can affect the sports skill level of peers who train together and often play in the same team. There can also be discrimination by coaches against players with lower fitness levels, which results from the pace of adolescence rather than a lack of commitment to training. Soccer coaches, guided mainly by the desire to achieve the best possible sports result, may favor players who stand out in terms of physical fitness or body size in selecting young players for the team. According to Lago-Peñas et al. (2014), such behavior can bring benefits only in the short term. Unfortunately, this may discourage some young athletes from taking up soccer. Maturation processes are also associated with changes in body height. In our study, goalkeepers were significantly taller than midfielders. This is consistent with studies analyzing the anthropometric profile of goalkeepers (Perez-Arroniz et al., 2023).

Similar results and a lack of statistically significant differences between isokinetic parameters and position on the field were reported by Gouveia et al. (2023). A lack of differences in the results of U15 players was also reported by Bona et al. (2017). Different results were presented by Herdy et al. (2018), who found that goalkeepers, compared to other players, developed the highest values of muscle torques at all measured movement velocities. Higher values of torques developed by goalkeepers at $60°\cdot s^{-1}$ compared to players from other positions and higher values of torques developed by defenders compared to midfielders were noted by Ruas et al. (2015).

In soccer, the lower limbs, especially the hamstrings, are at the greatest risk of injury (Hauge Engebretsen et al., 2010; Yamaner et al., 2011). To assess the risk of injury to the knee flexor muscles in soccer, isokinetic measurements are often used to determine the ratio of the strength capabilities of the antagonistic muscles whose function is to flex and extend the knee joint (H/Q ratio). There is the conventional H/Q ratio, an indicator that compiles the values of the torques developed during concentric contraction. It is suggested that at an angular velocity of $60°\cdot s^{-1}$, the H/Q ratio should be about 0.6 (Buśko et al., 2018; Dauty et al., 2003; Kim & Hong 2011). One can find an opinion that the value of the index should be 0.658 (Grygorowicz et al., 2017). Our evaluation of the H/Q ratio of muscle torques, total work, and average power showed no statistically significant differences between athletes in different positions. Another index used in the literature is the functional H/Q ratio, or the ratio of the strength capabilities of the flexors during eccentric contraction to the value of the torque developed by the knee extensors in concentric contraction (Daneshjoo et al., 2013; Forbes et al., 2009; Ruas et al., 2015; Zhang et al., 2021). For the velocity of $60°\cdot s^{-1}$, the ratio should be close to 1 (Ruas et al., 2015). In our study, we did not perform isokinetic measurements during eccentric contraction out of concern for the health of the young players.

In our study, a group of young male football players was examined, without including young female players, so the results of the study should not be extrapolated to female players, where the outcome may be different, especially among female adolescents. Our cohort meets the required size to ensure reliable results, but similar studies, especially on adult players, are often based on larger samples. Currently most research pertains to adult players; a greater number of studies on young players would provide more reliable answers regarding the influence of position on motor skills in young footballers. A limitation of this study is the uneven distribution of groups, especially the small number of goalkeepers and strikers. In our study, the training period of the players is known. However, we did not examine the influence of the training period on motor skills in individual positions, which may need to be considered in future studies.

Summary and conclusion

Among young players playing soccer in different positions, taking into account their specialization, no differences were found in the parameters of jumping abilities and isokinetic values. Although the players were characterized by similar strength and jumping potential, they differed in their ability to utilize it. Only some of the athletes showed a correlation between strength and jumping ability and depth of the swing performed before jumping. The differences in correlations are probably due to the different tasks and activities that players playing in different positions have to perform during the game. Motor skills in young athletes are certainly influenced by age, taking into account biological age, anthropometric development, sports skill level, and experience. To provide a better understanding of the changes in biomechanical parameters and the effect of the position on the field in soccer players, longitudinal evaluation of the group from early childhood (U13) at least until early adulthood (U23) would be advisable.

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