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Isokinetic strength and jumping abilities of teenage soccer players playing in different field positions

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Soccer is a sport being performed in a very dynamic manner. It requires soccer players to be able to develop high muscle force in a very short period of time. The aim of the study was to evaluate the strength and jumping abilities of young soccer players playing in different positions on the field. The study included 49 adolescent soccer players: 6 goalkeepers, 15 defenders, 17 midfielders and 11 strikers. 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 $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$ on a Biodex dynamometer, and jump height (H) and maximum power (P_{max}) on a force plate. PT, AP, TW, and P_{max} scores were normalized relative to body mass. There were no statistically significant differences between measurements of basic somatic characteristics (body height and body weight), age and biological age as well as PT, AP, TW, H, and P_{max} in players from different positions on the field. Unlike defenders, midfielders showed a significant correlation of isokinetic tests indices with jump height ($r = 0.54÷0.84$) and maximum relative power ($r = 0.55÷0.76$). The differences in correlations are probably due to the different tasks and activities that players in different positions on the field perform during the game.

Key words: *adolescent, countermovement jump, peak torque, football, performance*

1. Introduction

Soccer is a sport that places great physiological demand on players. Soccer players should have a high resistance to fatigue as they run long distances during a match, with games lasting more than 90 minutes [19], [35]. The way the game is played is constantly evolving. Although the total distance covered during a match does not change significantly, the number of short bouts of running at high speeds increases [4]. The initiation of high-intensity run requires the lower limb muscles to generate high power, which means, to perform high-volume work in a short time. There is a correlation between the ability to develop muscle power and the running speed and time required for soccer players to cover short distances [6], [12], [19], [24], [33].

Isokinetic measurements are one of the commonly used methods of assessing muscle strength among soccer players [4, 31, 36, 38]. During these, the speed of movement remains constant at a fixed level, and the torque developed by the muscle groups is measured [11]. Due to its high reproducibility, this method is considered the gold standard for measuring adolescent muscle strength potential, the ratio of strength capabilities of antagonistic muscle groups and their symmetry [23]. Another advantage of using isokinetic meas-

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urements over other methods is the ability to assess muscle strength under dynamic conditions [11]. These conditions are highly similar to football-specific movements made by players of different positions on the field. However, few studies have addressed the potential of strength developed under isokinetic contraction in players under the age of 15 [2], [6], [14].

In soccer, the muscles that support the knee joint are of paramount importance for performance. The high torque values developed by the quadriceps muscle group are considered as essential to perform efficient movements of the player on the field, ball kicking, and high jumps, while the hamstring muscles stabilize the knee joint and helps with locomotion [30]. Very often, the hamstrings performs eccentric contractions to deaccelerate the body. Due to the involvement of both antagonistic muscle groups in many motor activities during play, it becomes extremely important to develop them evenly. Yamaner et al. [41] reported that soccer players are most prone to lower limb soft tissue injury. It is assumed that an abnormal ratio of muscle strength of the knee flexors to extensors is a predictor of knee joint injury [16].

It has been suggested that the amount and type of different activities on the field may be related to the position of a player on the field [30]. Specific anthropometric features and motor skills can be a criterion for talent identification and for selecting a player to play in a particular position during the game [12]. The scientific literature contains examples of papers that have analyzed differences in anthropometry [1], [12], [26], [32], muscular strength [2], [3], [14], and other elements of physical fitness [12], [26] that occur between teenage soccer players playing in different field positions. According to Lago-Peñas et al. [18], studies examining the prevalence of differences between adolescent players with different roles on the soccer field are fewer in number than those on professional players, with their results being inconsistent.

The selection of training loads during preparation of teenage athletes should be appropriate to the motor capabilities of the players of selected field position. Preparing a young athlete for the specific demands of the occupied position on the field will involve differentiating the training of individuals. Differences in the ability of players of different positions to develop muscular strength and power should be reflected through the selection of training loads. It seems reasonable, therefore, to assess the motor capabilities of football players in the U15 category. The aim of the study was to evaluate the differences in strength and jumping abilities of adolescent soccer players playing in different field positions.

2. Materials and methods

2.1. Participants

The study involved 49 adolescent soccer players from three of Polish top soccer clubs. The players were divided according to their position on the field: 6 goalkeepers, 15 defenders, 17 midfielders and 11 strikers. The study was approved by the Bioethics Committee of the Ethics 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. Basic somatic characteristics are presented in Table 1.

Players playing in different positions on the field did not differ significantly in chronological or biological age and training experience. Although the analysis of variance indicated the presence of a statistically significant difference in body height, the post-hoc analy-

Table 1. Demographic data. Mean values (±SD) and 95% confidence intervals of age, body mass and body height of players playing in different positions on the field

	GK (n = 6)	DEF (n = 15)	MID (n = 17)	ST (n = 11)	F	p	η^2
Age [years]	14.53 ± 0.68 (13.82÷15.24)	14.27 ± 0.41 (14.04÷14.50)	14.41 ± 0.53 (14.14÷14.68)	14.42 ± 0.51 (14.08÷14.76)	0.45	0.72	0.03
Biological age [years]	15.44 ± 2.15 (13.18÷17.70)	15.13 ± 1.11 (14.52÷15.75)	14.97 ± 1.32 (14.29÷15.65)	15.40 ± 1.56 (14.35÷16.45)	0.28	0.84	0.02
Years of training [years]	6.00 ± 1.26 (4.67÷7.33)	6.13 ± 1.46 (5.33÷6.94)	6.71 ± 0.92 (6.23÷7.18)	6.45 ± 0.82 (5.90÷7.01)	0.94	0.43	0.06
Body height [cm]	181.17 ± 10.40 (170.25÷192.08)	171.27 ± 8.51 (166.55÷175.98)	167.06 ± 9.49 (162.18÷171.94)	172.64 ± 10.89 (165.32÷179.95)	3.26	0.03	0.18
Body weight [kg]	67.45 ± 14.53 (52.20÷82.70)	58.53 ± 9.67 (53.17÷63.88)	55.94 ± 10.79 (50.40÷61.49)	61.76 ± 13.81 (52.49÷71.04)	1.63	0.20	0.10

GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers.

sis showed no statistically significant (p = 0.068) differences between players playing in different positions.

2.2. Measurement protocol

Design and procedures

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. The players signed the relevant statements, and their legal guardians gave written informed consent for the examination. Anthropometric measurements of the players were taken under the supervision of a qualified research team, followed by an individual warm-up. The warm-up included jumps, runs over a distance of several meters, basic gymnastic exercises and stretching. After the player was ready, the isokinetic measurements were performed, followed by the jumping tests.

Anthropometric measurements

One person performed anthropometric tests using the International Society for the Advancement of Kinanthropometry (ISAK) protocols [24]. Body height and sitting height were determined using a SiberHegner anthropometer (Switzerland), whereas body mass was measured using a Tanita TBF 300 body composition analyzer (Japan). The degree of biological development of the soccer players was determined by anthropometric measurements (body height and sitting height, estimated leg length and body mass) using the age at peak height velocity (APHV) method [22].

Isokinetic strength

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. The player sat in a seat with the backrest tilted 15° 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 joint axis 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. The players performed the measurements at the movement velocities of $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $300°\cdot s^{-1}$. There was a 30-second break between the series of movements with each measured speed. The largest recorded value of the muscle torque 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.

Power output and height of jump

The power output of lower extremities (P_{max}) and the height (H) of the center of mass (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. Relative peak power (power $\cdot$ mass^{-1} [W $\cdot$ kg^{-1}]) and maximum height of the body's COM (h [cm]) were calculated from the recorded ground reaction force. Each participant performed nine vertical jumps on the force plate: three jumps of each kind. There was a 5 second break between each jump in the series and a 1 minute break between each series of jumps. The characteristics of each jumping test were the following:

- ACMJ – akimbo counter-movement jump – a vertical jump without arm swing 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 tested player jumps on a platform from few meters run-up with by an arm-swing and counter-movement of the body COM before the take-off. The analysis included the highest jump from each type.

Statistical analysis

Descriptive statistical analysis consisted in the determination of mean values, standard deviations, and 95% confidence intervals of the means of the indices studied. The normality of the distribution of variables was verified using the Shapiro–Wilk test. Furthermore, we used the Levene's test and the Mauchly's test to evaluate homogeneity and sphericity of variance, respectively. One-way analysis of variance (ANOVA) was used to evaluate differences in anthropological indices (Table 1). A two-way analysis of variance with a repeated-measures design 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 ($0.01 < \eta^2 \le 0.06$), medium ($0.06 < \eta^2 \le 0.14$), and large ($\eta^2 > 0.14$) [7]. 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 post-hoc using Tukey's test with correction for different group sizes. If the assumption of homogeneity of variance was not met, the Dunett 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 ($0.1 < R \le 0.5$), or large ($R > 0.5$) [7]. A 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).

3. Results

In Table 2, the results of the jumping test are contained. In the analysis of jump height (H) and maximum relative power (P_{max}), there was no statistically significant effect of the player's position on the field. The players tested, performing successive jumping tests, obtained significantly different values for their jump height ($F_{2.90} = 380$; $p < 0.05$) and maximum relative power ($F_{2.90} = 229$; $p < 0.05$). The effect size was found to be large in both cases. There was no statistically significant interaction between the type of jump and the position in which the players played.

In Table 3, the results of measurements of peak torques (PT), total work (TW), and muscle average power (AP) developed under isokinetic conditions are shown. The results characterizing the muscle groups of the knee extensors and flexors were not significantly different between the playing positions on the field. The players, performing concentric extension and flexion movements at the knee joint at different angular velocities, developed different peak torque values ($F_{2.90} = 544$; $p < 0.05$ and $F_{2.90} = 215$; $p < 0.05$, respectively). There was a statistically significant difference between the average power of the quadriceps ($F_{2.90} = 371$; $p < 0.05$) developed only at velocities of $300°\cdot s^{-1}$ and $60°\cdot s^{-1}$ ($p < 0.05$) and $180°\cdot s^{-1}$ and $60°\cdot s^{-1}$ ($p < 0.05$). The average power generated by the biceps femoris muscles differed significantly for movements at all velocities studied ($F_{2.90} = 92$; $p < 0.05$). Although the results of the analysis of variance indicate the presence of a statistically significant difference between the values of the total work of the knee flexor muscle group performed by players playing in different positions on the field ($F_{2.90} = 2.82$; $p < 0.05$), the post hoc analysis showed the absence of statistically significant differences. Total work performed during knee extension and flexion at different angular velocities was statistically different ($F_{2.90} = 264$; $p < 0.05$ and $F_{2.90} = 206$; $p < 0.05$, respectively). 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 2. Jump height and maximum relative power developed during vertical jumps

	Jump type	GK (n = 6)	DEF (n = 15)	MID (n = 17)	ST (n = 11)	Interaction	F	p	η^{2_2}
H [cm]	ACMJ	34.53 ± 4.62 (29.68÷39.39)	33.67 ± 3.62 (31.66÷35.67)	32.70 ± 3.82 (30.73÷34.67)	33.48 ± 4.07 (30.75÷36.22)	position	0.65	0.59	0.04
	CMJ	41.45 ± 6.93 (34.17÷48.73)	40.41 ± 4.06 (38.16÷42.65)	38.67 ± 5.55 (35.82÷41.52)	39.72 ± 5.48 (36.04÷43.40)	jump type	380	<0.001	0.89
	BCMJ	50.70 ± 9.47 (40.76÷60.64)	48.74 ± 4.38 (46.31÷51.17)	46.81 ± 5.59 (43.93÷49.68)	47.47 ± 5.42 (43.83÷51.12)	position × jump type	0.38	0.84	0.02
P_{max} [$W \cdot kg^{-1}$]	ACMJ	21.53 ± 6.44 (14.78÷28.29)	22.64 ± 4.69 (20.04÷25.24)	20.86 ± 4.18 (18.71÷23.01)	23.41 ± 3.32 (21.18÷25.64)	position	0.34	0.80	0.02
	CMJ	30.72 ± 7.57 (22.77÷38.66)	31.03 ± 4.51 (28.53÷33.53)	30.00 ± 6.42 (26.69÷33.30)	32.99 ± 7.57 (27.91÷38.07)	jump type	229	<0.001	0.84
	BCMJ	46.28 ± 7.71 (38.19÷54.37)	44.77 ± 10.48 (38.97÷50.58)	47.60 ± 13.86 (40.47÷54.73)	48.74 ± 7.57 (43.66÷53.83)	position × jump type	0.59	0.67	0.04

H – jump height, P_{max} – maximum relative power, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers.

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

	Angular velocity [°·s^{-1}]	GK (n = 6)	DEF (n = 15)	MID (n = 17)	ST (n = 11)	Interaction	F	p	η^2
EPT [N·m]	300	1.41 ± 0.18 (1.22÷1.60)	1.50 ± 0.16 (1.42÷1.59)	1.43 ± 0.21 (1.32÷1.54)	1.47 ± 0.22 (1.32÷1.62)	position	0.68	0.57	0.04
	180	1.91 ± 0.34 (1.56÷2.27)	2.01 ± 0.16 (1.93÷2.10)	1.91 ± 0.31 (1.75÷2.06)	1.96 ± 0.20 (1.83÷2.10)	angular velocity	544	<0.001	0.92
	60	2.80 ± 0.63 (2.14÷3.45)	2.78 ± 0.34 (2.59÷2.96)	2.56 ± 0.43 (2.34÷2.78)	2.70 ± 0.26 (2.52÷2.87)	position × angular velocity	1.13	0.35	0.07
FPT [N·m]	300	0.84 ± 0.15 (0.68÷0.99)	0.92 ± 0.13 (0.85÷1.00)	0.96 ± 0.11 (0.91÷1.02)	0.96 ± 0.21 (0.82÷1.10)	position	0.64	0.59	0.04
	180	0.99 ± 0.18 (0.81÷1.18)	1.13 ± 0.14 (1.06÷1.21)	1.16 ± 0.18 (1.07÷1.26)	1.15 ± 0.13 (1.06÷1.24)	angular velocity	215	<0.001	0.83
	60	1.57 ± 0.29 (1.26÷1.88)	1.54 ± 0.32 (1.36÷1.72)	1.50 ± 0.26 (1.36÷1.63)	1.62 ± 0.12 (1.54÷1.70)	position × angular velocity	1.43	0.23	0.09
EAP [W · kg^{-1}]	300	3.28 ± 0.55 (2.70÷3.85)	3.86 ± 0.48 (3.59÷4.13)	3.74 ± 0.86 (3.30÷4.18)	3.86 ± 0.75 (3.36÷4.37)	position	0.87	0.46	0.05
	180	3.36 ± 0.71 (2.62÷4.11)	3.73 ± 0.44 (3.48÷3.97)	3.59 ± 0.59 (3.29÷3.90)	3.67 ± 0.38 (3.41÷3.92)	angular velocity	371	<0.001	0.89
	60	1.79 ± 0.37 (1.40÷2.18)	1.83 ± 0.25 (1.69÷1.97)	1.70 ± 0.35 (1.52÷1.88)	1.77 ± 0.21 (1.63÷1.91)	position × angular velocity	1.09	0.37	0.07
FAP [W · kg^{-1}]	300	1.18 ± 0.60 (0.55÷1.81)	1.79 ± 0.49 (1.52÷2.06)	1.81 ± 0.67 (1.47÷2.16)	1.84 ± 0.57 (1.45÷2.22)	position	2.13	0.11	0.12
	180	1.63 ± 0.53 (1.07÷2.19)	2.03 ± 0.31 (1.86÷2.2)	2.02 ± 0.44 (1.80÷2.25)	2.10 ± 0.33 (1.88÷2.32)	angular velocity	89	<0.001	0.67
	60	0.99 ± 0.29 (0.68÷1.29)	1.05 ± 0.24 (0.92÷1.18)	1.02 ± 0.21 (0.91÷1.13)	1.10 ± 0.13 (1.01÷1.19)	position × angular velocity	1.44	0.23	0.09
ETW [J · kg^{-1}]	300	4.23 ± 0.72 (3.47÷4.99)	5.05 ± 0.59 (4.72÷5.38)	5.16 ± 1.27 (4.51÷5.82)	5.29 ± 0.88 (4.69÷5.88)	position	1.16	0.33	0.07
	180	6.05 ± 1.12 (4.87÷7.23)	6.89 ± 0.98 (6.35÷7.44)	6.81 ± 1.42 (6.08÷7.54)	7.04 ± 0.80 (6.50÷7.58)	angular velocity	264	<0.001	0.85
	60	7.34 ± 1.22 (6.06÷8.62)	8.44 ± 1.14 (7.81÷9.08)	7.91 ± 1.98 (6.89÷8.93)	8.22 ± 1.16 (7.44÷9.00)	position × angular velocity	0.84	0.52	0.05
FTW [J · kg^{-1}]	300	1.71 ± 0.84 (0.83÷2.59)	2.65 ± 0.66 (2.29÷3.02)	2.79 ± 1.02 (2.27÷3.31)	2.77 ± 0.81 (2.22÷3.31)	position	2.82	0.05	0.16
	180	3.05 ± 0.97 (2.03÷4.06)	4.15 ± 0.64 (3.80÷4.51)	4.29 ± 1.16 (3.69÷4.88)	4.69 ± 1.13 (3.93÷5.45)	angular velocity	206	<0.001	0.82
	60	4.67 ± 1.20 (3.41÷5.92)	5.34 ± 1.27 (4.64÷6.05)	5.07 ± 1.16 (4.48÷5.66)	5.74 ± 0.75 (5.24÷6.24)	position × angular velocity	1.36	0.25	0.08

EPT – extensors peak torque, FPT – flexors peak torque, EAP – extensors average power, FAP – flexors average power, ETW – extensors total work, FTW – flexors total work, GK – goalkeepers, DEF – defenders, MID – midfielders, ST – strikers.

In Table 4, the values of the ratios of torques of the knee flexors to extensors (H/Q ratio), the total work and the average power developed under isokinetic conditions are shown. The ratio of peak torques developed by the biceps femoris and the quadriceps did not differ statistically significantly in players playing in different positions on the field. There was a statistically significant difference ($F_{2.90}$ = 11; p < 0.05) between the ratios of strength abilities of the hamstrings and the quadriceps during movements at velocities of 300°·s^{-1} and 60°·s^{-1} (p < 0.05) and 180°·s^{-1} and 60°·s^{-1} (p < 0.05). The ratio of average power developed and total work performed by the knee flexors and extensors differed significantly in movements at all measured velocities ($F_{2.90}$ = 62; p < 0.05, $F_{2.90}$ = 48; p < 0.05, respectively). 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.

In Table 5, the values of Pearson correlation coefficients evaluating the relationship between the results of the jumping tests and selected results of isokinetic measurements of defenders and midfielders are shown. Due to the small size of the groups of goalkeepers (n = 6) and strikers (n = 11), it was decided not to include the results in the interpretation. However, the

Table 4. Values of peak torque, total work, and average power developed by the knee flexors and extensors under isokinetic conditions

	Angular velocity [°·s^{-1}]	GK (n = 6)	DEF (n = 15)	MID (n = 17)	ST (n = 11)	Interaction	F	p	η^2
PT H/Q ratio [–]	300	0.61 ± 0.14 (0.46÷0.75)	0.62 ± 0.06 (0.58÷0.65)	0.68 ± 0.10 (0.63÷0.74)	0.66 ± 0.12 (0.57÷0.74)	position	2.11	0.11	0.12
	180	0.52 ± 0.06 (0.46÷0.58)	0.56 ± 0.06 (0.53÷0.60)	0.62 ± 0.11 (0.56÷0.68)	0.59 ± 0.05 (0.55÷0.62)	angular velocity	11	<0.001	0.20
	60	0.57 ± 0.10 (0.46÷0.68)	0.55 ± 0.09 (0.50÷0.60)	0.59 ± 0.09 (0.54÷0.64)	0.61 ± 0.08 (0.55÷0.66)	position × angular velocity	0.67	0.64	0.04
AP H/Q ratio [–]	300	0.35 ± 0.13 (0.21÷0.48)	0.46 ± 0.09 (0.41÷0.51)	0.48 ± 0.15 (0.41÷0.56)	0.47 ± 0.09 (0.41÷0.52)	position	2.44	0.08	0.14
	180	0.47 ± 0.11 (0.35÷0.58)	0.55 ± 0.06 (0.51÷0.58)	0.57 ± 0.12 (0.51÷0.63)	0.57 ± 0.06 (0.53÷0.61)	angular velocity	62	<0.001	0.58
	60	0.55 ± 0.09 (0.45÷0.64)	0.57 ± 0.08 (0.53÷0.61)	0.61 ± 0.09 (0.56÷0.65)	0.63 ± 0.07 (0.58÷0.67)	position × angular velocity	0.94	0.45	0.06
TW H/Q ratio [–]	300	0.39 ± 0.14 (0.24÷0.54)	0.52 ± 0.09 (0.47÷0.57)	0.54 ± 0.16 (0.46÷0.62)	0.52 ± 0.09 (0.45÷0.58)	position	2.25	0.10	0.13
	180	0.50 ± 0.11 (0.38÷0.62)	0.60 ± 0.07 (0.57÷0.64)	0.63 ± 0.13 (0.57÷0.70)	0.67 ± 0.15 (0.56÷0.77)	angular velocity	48	<0.001	0.52
	60	0.63 ± 0.12 (0.51÷0.76)	0.63 ± 0.11 (0.57÷0.69)	0.65 ± 0.09 (0.60÷0.70)	0.71 ± 0.10 (0.64÷0.77)	position × angular velocity	2.03	0.07	0.12

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

Table 5. Values of Pearson correlation coefficients between results of jumping tests and results of isokinetic measurements of the quadriceps

	Angular velocity [°·s^{-1}]	H [cm]						P_{max} [W · kg^{-1}]					
		DEF (n = 15)			MID (n = 17)			DEF (n = 15)			MID (n = 17)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
EPT [N · m]	300	0.10	0.11	–0.01	0.63*	0.82*	0.84*	–0.09	0.22	0.18	0.55*	0.72*	0.46
	180	0.38	0.33	0.26	0.61*	0.76*	0.74*	0.08	0.03	0.35	0.71*	0.76*	0.64*
	60	0.38	0.28	0.36	0.66*	0.73*	0.58*	–0.07	–0.10	0.30	0.74*	0.74*	0.70*
EAP [W · kg^{-1}]	300	0.11	0.11	–0.04	0.56*	0.70*	0.81*	0.02	0.24	0.20	0.33	0.57*	0.28
	180	0.28	0.33	0.49	0.59*	0.75*	0.72*	0.14	0.40	0.58*	0.65*	0.74*	0.56*
	60	0.46	0.42	0.55*	0.59*	0.70*	0.54*	0.00	0.14	0.42	0.59*	0.66*	0.56*
ETW [J · kg^{-1}]	300	0.05	0.04	0.04	0.56*	0.71*	0.81*	–0.01	0.30	0.29	0.35	0.56*	0.34
	180	0.08	0.15	0.40	0.62*	0.78*	0.75*	0.03	0.40	0.55*	0.59*	0.71*	0.52*
	60	0.22	0.30	0.33	0.63*	0.76*	0.71*	–0.09	0.07	0.30	0.57*	0.70*	0.57*

EPT – extensors peak torque, EAP – extensors average power, ETW – extensors total work, H – jump height, P_{max} – maximum relative power, DEF – defenders, MID – midfielders, * – statistically significant correlation $p < 0.05$.

results of the statistical calculations are included in Supplement 1.

Of all three jumping tests, the jump height in midfielders correlated significantly ($p < 0.05$) with the peak torque, average power and total work done by the quadriceps muscles during isokinetic measurements. For defenders, there was only a correlation between the BCMJ's jump height and the average power generated by the quadriceps during movements at 60°·s^{-1}. The ratio of the value of power generated during vertical jumps to body mass in the group of midfielders correlated significantly with the indices obtained during isokinetic measurements of the quadriceps. The exceptions were the lack of significant correlation between the relative power developed in the ACMJ and BCMJ jumps, as well as the total work and the average power generated during movements at 300°·s^{-1}. Furthermore, there was no statistically significant relationship between relative power in the BCMJ jump and peak torque during movement at 300°·s^{-1}. In the group of defenders, there were statistically significant correlations only for total work and average power generated at $180^{\circ}\cdot s^{-1}$ and peak relative power generated during BCMJ jumps.

4. Discussion

The most important observation of our study is the difference between midfielders and defenders. In contrast to defenders, there was a correlation in midfielders between jumping test results and isokinetic measurements. However, we did not find differences in the jump height, peak power, and muscle strength developed under isokinetic conditions by the adolescent soccer players playing in different positions on the field.

Isokinetic strength potential of players of different positions

The differences that exist between professional players performing different roles on the field have been the subject of many studies [4], [31], [32], [36]. Different levels of flexor and extensor muscle strength in the knee joint in players playing in different positions on the field were previously recorded by Ruas et al. [30], Salguero et al. [31] or Śliwowski et al. [36], whereas Tourny-Chollet et al. [38] found differences only in the torques developed by the hamstrings. Studies available in the literature on the prevalence of differences in the ability of teenage soccer players playing in different positions on the field to develop muscle strength are inconclusive [18]. Our research shows that teenage players playing in different positions exhibit similar levels of relative muscle strength. Results showing that there were no differences in strength potential were also observed in the studies by Bona et al. [2] and Bonetti et al. [3]. Furthermore, in a study by Herdy et al. [14] goalkeepers, compared to other players, developed the highest values of muscle torques at all measured movement velocities. It should be emphasized, however, that Herdy et al. [14] analyzed the absolute values of muscle torques, while our study focused on the ratios of the torques to the body mass of the participants. According to Scoz et al. [32], differences in strength potential might no longer be significant as a result of the normalization of isokinetic test results to body mass. The goalkeepers are often characterized by the greatest body height and body mass [13], [27], [28]. The larger size of the lower limbs requires the development of larger absolute values of muscle torques during dynamic soccer movements. In the case of the players in our study, the goalkeepers were not significantly distinguished by their body mass and height. However, it is important to keep in mind the small size of the group of players participating in the study. It is worth noting that the results of the statistical analysis indicated the presence of a tendency for differences between groups, with the $p = 0.068$ close to the accepted significance level of $p = 0.05$. This indicates the need for further research in this field.

The muscle torques we recorded decreased when developed under isokinetic conditions at progressively higher velocities. This is consistent with the research of many authors [8], [10], [19] and is based on the physiological capacity of muscles to develop forces as described by Hill [15].

Muscle strength imbalance

It is important that soccer training of adolescent players should lead to their sustainable development. An imbalance in the strength abilities of the knee flexors and extensors is considered as a predictor of injury [16]. In our study, there were no differences in the ratios of the strength of the antagonistic muscle groups of the knee joint in players playing in different positions on the playing field. H/Q ratios at a velocity of $60^{\circ}\cdot s^{-1}$ were close to the value of 0.6, which is recommended and consistent with the results of many authors [5], [25], [30], [36]. Correct proportions of the torques developed by antagonistic muscle groups testify to a well-conducted training process of the studied young athletes. The results of other authors show the increasing contribution of biceps femoris strength to the H/Q ratio and an increase in the value of the ratio for increasing rotational velocity of movements in isokinetic measurements [5], [8], [10], [19]. The H/Q ratios recorded in our study at $60^{\circ}\cdot s^{-1}$ differed from those obtained at the other two velocities. Noteworthy are the small H/Q ratios recorded at $300^{\circ}\cdot s^{-1}$, averaging from 0.61 for goalkeepers to 0.68 for midfielders. These values are consistent with the results presented by [20], [30]. However, many authors have documented slightly higher results, exceeding the ratios of 0.7 [5], [10], and even reaching 0.8 [8]. According to Ramos et al. [29], the age of participants does not affect the value of the ratio. Therefore, it is likely that the differences between the reports are due to the different training the groups participating in each study performed.

Jumping abilities of players of different positions

The quadriceps and hamstrings are muscles used very often in soccer. They participate in locomotion, jumping, and kicking the ball. These are dynamic movements in which strength must be developed explosively. Jumping tests are commonly used to assess muscle power. Similar to our study, no statistically significant differences in CMJ jump height between players playing in different positions were found by other researchers [1], [12], [17], [18]. In a study by Portes et al. [28], goalkeepers were distinguished from other players by jumping the highest. Other studies [2], [13], [26] showed differences in jump height between midfielders and strikers. The ability to move efficiently on the field is critical to the game of soccer. There is a relationship between jumping ability and running speed and time required for soccer players to cover short distances [6], [12], [25], [33]. Jumping abilities have also been shown to be related to agility [12] and the ability to quick change of running direction [21]. In our study, there was a correlation of maximum muscle torque with jumping ability and power developed during jumps in midfielders, which was not observed in defenders. Although the midfielders we studied had similar strength potential to defenders, it is possible that they used it in slightly different ways. The player in different positions have different roles on the field. The different activities performed during the game may contribute to the development of a slightly different jumping movement technique in midfielders than in defenders. Therefore, the correlation of strength with jumping ability occurs only in midfielders. The task of the midfielders is to support the strikers and organize offensive actions. A similar correlation of isokinetic and jumping tests was documented in strikers by Buśko et al. [5]. When planning an attacking action, midfielders wishing to use the element of surprise must break free from the opposing team's defenders, for example, by suddenly accelerating and overtaking their adversaries. Vigne et al. [39] noted that midfielders are more likely than other players to cover distances between 2 and 9 meters and between 30 and 40 meters, and a greater total distance during the game. In our study, we analyzed peak torque, but we did not measure the rate of torque development, which is correlated with jumping ability [37]. The ability of muscles to develop large forces faster enables the athletes to overcome the inertia of their own body when accelerating and moving at higher speeds. The occurrence of relationship between isokinetic and jumping tests may also be due to the process of selecting players for the team. The coaches of the players studied, guided by their observations of the way the teenagers move around the field during training and control games, make decisions about assigning players to play in specific positions.

Maturation and the motor capabilities

When evaluating the strength and speed abilities of young soccer players, it is important to keep in mind their biological age. Young athletes who start the process of maturation earlier may show higher levels of motor abilities than their peers [40]. Chuman et al. [6] demonstrated that muscle strength, which shows a relationship with jump height and running speed over short distances, results from muscle size, which is influenced by sexual maturity. This is related to the concentration of testosterone, a hormone that is responsible for anabolic properties desired in sports training and which has been shown to be related to the elevation of the center of body mass during jumping [9]. In our study, the rate of biological development of the players studied was evaluated by determining their biological age. We found no statistically significant differences in the biological age of adolescents. That observation leads to the assumption that observed differences resulted from playing positions, not the maturity of players.

The results of our study contribute to the ongoing discussion of the differences in the strength and jumping abilities of young soccer players playing in different positions on the field. However, it should be noted that the study also has some limitations. The first limitation is the small number of study participants. For this reason, the results of players playing in the goalkeeper and striker positions were excluded from some parts of the analysis.

5. Conclusions

We did not find differences in the jump height, peak power and muscle strength developed under isokinetic conditions by the teenage soccer players playing in different field positions. This leads us to believe that the training loads to which young players playing in different positions are subjected are similar.

However, we found a correlation between jumping test results and isokinetic measurements in midfielders, which was not found in defenders group. It indicates that players with similar strength potential, who perform a different tasks and activities during the game, may perform different strategies to exploit it. Coaches, selecting players for midfield positions, should pay attention in the selection process to the ability of players to effectively use their strength potential and their ability to develop muscle power during the game.

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Supplement 1

Table 1. Values of Pearson correlation coefficients between height of jumps and results of isokinetic measurements of the quadriceps

	Angular velocity [°·s^{-1}]	*H* [cm]											
		GK (*n* = 6)			DEF (*n* = 15)			MID (*n* = 17)			ST (*n* = 11)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
EPT [N·m]	300	0.88*	0.88*	0.75	0.10	0.11	–0.01	0.63*	0.82*	0.84*	0.71*	0.65*	0.67*
	180	0.79	0.79	0.71	0.38	0.33	0.26	0.61*	0.76*	0.74*	0.57	0.52	0.37
	60	0.72	0.77	0.69	0.38	0.28	0.36	0.66*	0.73*	0.58*	0.69*	0.69*	0.51
EAP [W · kg^{-1}]	300	0.44	0.43	0.36	0.11	0.11	–0.04	0.56*	0.70*	0.81*	0.60	0.51	0.51
	180	0.83*	0.85*	0.87*	0.28	0.33	0.49	0.59*	0.75*	0.72*	0.68*	0.62*	0.44
	60	0.79	0.86*	0.80	0.46	0.42	0.55*	0.59*	0.70*	0.54*	0.58	0.51	0.26
ETW [J · kg^{-1}]	300	0.39	0.39	0.29	0.05	0.04	0.04	0.56*	0.71*	0.81*	0.47	0.42	0.42
	180	0.77	0.83*	0.71	0.08	0.15	0.40	0.62*	0.78*	0.75*	0.61*	0.58	0.43
	60	0.78	0.88*	0.87*	0.22	0.30	0.33	0.63*	0.76*	0.71*	0.69*	0.65*	0.42

EPT – extensors peak torque, EAP – extensors average power, ETW – extensors total work, *H* – jump height, GK –goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, * – statistically significant correlation $p < 0.05$.

Table 2. Values of Pearson correlation coefficients between maximum relative power and results of isokinetic measurements of the quadriceps

	Angular velocity [°·s^{-1}]	P_{max} [W · kg^{-1}]											
		GK (*n* = 6)			DEF (*n* = 15)			MID (*n* = 17)			ST (*n* = 11)		
		ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ	ACMJ	CMJ	BCMJ
EPT [N·m]	300	0.89*	0.80	0.33	–0.09	0.22	0.18	0.55*	0.72*	0.46	0.79*	0.75*	0.24
	180	0.98*	0.83*	0.54	0.08	0.03	0.35	0.71*	0.76*	0.64*	0.58	0.52	0.36
	60	0.89*	0.92*	0.50	–0.07	–0.10	0.30	0.74*	0.74*	0.70*	0.67*	0.62*	0.34
EAP [W · kg^{-1}]	300	0.18	0.06	–0.08	0.02	0.24	0.20	0.33	0.57*	0.28	0.67*	0.60*	0.29
	180	0.91*	0.88*	0.79	0.14	0.40	0.58*	0.65*	0.74*	0.56*	0.70*	0.66*	0.48
	60	0.87*	0.96*	0.59	0.00	0.14	0.42	0.59*	0.66*	0.56*	0.68*	0.75*	0.73*
ETW [J · kg^{-1}]	300	0.15	0.05	–0.17	–0.01	0.30	0.29	0.35	0.56*	0.34	0.56	0.50	0.30
	180	0.86*	0.90*	0.39	0.03	0.40	0.55*	0.59*	0.71*	0.52*	0.66*	0.61*	0.49
	60	0.76	0.95*	0.68	–0.09	0.07	0.30	0.57*	0.70*	0.57*	0.69*	0.73*	0.61*

EPT – extensors peak torque, EAP – extensors average power, ETW – extensors total work, P_{max} – relative power, GK –goalkeepers, DEF – defenders, MID – midfielders, ST – strikers, * – statistically significant correlation $p < 0.05$.