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Lower extremity muscle strength, postural stability and functional movement screen in female basketball players after ACL reconstruction. Preliminary report

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Purpose: The anterior cruciate ligament (ACL) tear is a common injury in basketball. Its consequence is a long absence from training, resulting from surgical treatment and long physiotherapy. The aim of the study was to assess muscle strength, postural stability and functional movements in female basketball players, who returned to professional sport careers after anterior cruciate ligament reconstruction. *Methods*: The study population consisted of 10 female basketball players after surgical reconstruction of anterior cruciate ligament. The control group consisted of 10 players without ACL injury. We used the Biodex System 4 Pro dynamometer to assess the muscle strength of the knee. We used it to conduct the test of flexors and extensors of the knee in isokinetic conditions. We also used Keiser Power Squat A300 in the single leg squat to measure power and the Biodex Balance SD dynamographic platform to assess balance in single leg stance. *Results*: We found deficits in both movement patterns and in muscle strength in the study population, compared to control group. *Conclusions*: The basketball players after ACL reconstruction had significant differences between the operated and non-operated limb. The differences may predispose them towards repeated ACL injuries.

Key words: *basketball players, ACL reconstruction, functional stability, muscle strength*

1. Introduction

Professional sport training is related to significant strain of the locomotor system resulting from intense training and frequent matches. Improper training load may lead to injuries [11]. The most common injuries among basketball players are injuries to the fingers, ankle sprains and injuries to the knees. One of the most common injuries of the knee is anterior cruciate ligament tear. The injury forces the athlete to stop their physical activity, requires surgical reconstruction of the ACL and long lasting physiotherapy, so that eventually the athlete may regain full ability and return to sport [9]. The available literature lacks information on the functional state of professional basketball players after surgical reconstruction of the ACL and completed physiotherapy. Reports suggest that it is crucial to monitor muscle strength [7], [8], and neuro-muscular control, in basketball players, with the use of objective tools [20].

The aim of the study was to assess muscle strength, postural stability and quality of movement patterns according to the FMS method in female basketball players after surgical reconstruction of the ACL who returned to professional sports.

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2. Materials and methods

We obtained the consent of the Senate Commission for Scientific Research of the University of Physical Education in Warsaw, no. SKE 01-48/2017. The study involved 20 professional female basketball players from different leagues. The study population included 10 professional basketball players after surgical reconstruction of ACL and after physiotherapy. The control group consisted of 10 players who did not have ACL injuries. Table 1 presents biometric data. There were no statistically significant differences between the groups in this regard.

body temperature, dynamic stretching and progressive load in the pattern of squat and one leg squat. For the following two, the basketball players had identical warm up which took 10 minutes and consisted of the following exercise done on the Squat A300 device:

a) two series of eight repetitions in the pattern of both feet squat with the load equal to the body mass of the subject,
b) two series of eight repetitions in the pattern of one foot squat with the load equal to 1/2 of the body mass of the subject,
c) two series of eight repetitions in the pattern of one foot squat with the load equal to 3/4 of the body mass of the subject.

Table 1. Characteristics of the studied groups

Variables	Study population					Control group					*t*/*Z*	*P*
	$\bar{x}$	Me	Min	Max	SD	$\bar{x}$	Me	Min	Max	SD		
Age	23.30	22.00	20.00	33.00	3.95	22.00	21.00	18.00	31.00	4.11	1.17	0.236
Body height [cm]	174.40	172.50	163.00	186.00	8.95	177.00	178.00	160.00	190.00	8.78	–0.66	0.520
Body mass [kg]	70.40	71.50	58.00	82.00	7.56	73.10	74.00	60.00	80.00	5.97	–0.89	0.387

In both groups, the dominant upper limb was usually the right limb. There were no statistically significant differences in this respect ($p = 0.304$). In 8 athletes after ACL reconstruction the operated lower limb was the left limb. The mean time since the surgery was 3.2 ± 1.23 years. In most cases, the reconstruction used tissue taken from muscles: the semitendinous muscle or the gracilis muscle.

Before the measurements, the basketball players learned the method of the study and signed their consents to participate in the study. The method of the study consisted of measurements taken in the following order:

1) functional movement screen (FMS),
2) postural stability test – one leg stance of the Biodex Balance System SD platform,
3) one leg squat test with pneumatic load, with the use of the Keiser Power Squat A300 device,
4) muscle strength test of flexors and extensors of the knee in isokinetic conditions with the use of the Biodex System4 Pro dynamometer.

We followed recommendations described in the literature and we did not ask the subjects to do warm up before the functional screen [15]. Before the postural stability test, the subjects learned the details of the test on stable and unstable surface on the Biodex Balance SD dynamographic platform.

Before the power assessment of the Keiser Power Squat A300 there was warm up. It involved increasing

Before the muscle strength test of the flexors and extensors of the knee in isokinetic conditions with the use of Biodex System4 Pro dynamometer, the studied players learned both the details of the assessment on the dynamometer and the details of measurements in isokinetic conditions for every angular velocity.

The FMS functional movement screen allows for qualitative assessment of the quality of performance of basic movement patterns and determining whether there are any limitations or asymmetries. The screen consists of seven basic tests, i.e., 1) deep squat, 2) hurdle step, 3) inline lunge, 4) shoulder mobility, 5) active straight-leg raise, 6) trunk stability push-up, 7) rotary stability. Each test was assessed on a 0 to 3 point scale, where 0 points denotes pain during the test, 1 point denotes inability to perform the test according to instructions, 2 points denote performing the test with compensation, and 3 points denote performing the test correctly. The maximum number of points to score was 21. The FMS was conducted in sports clothes and basketball shoes [15].

The second assessment was the assessment of postural stability, one leg, on the Biodex Balance System SD platform. The subjects did one leg stance on dynamographic platform. The protocol consisted of three trials lasting 30 seconds each, with 10-second break, without changing body position. There were three trials on stable surface and three trials on unstable surface, whose degree of stability was 4, according to the methodology described in the literature [16].

During the trials, we restricted the view of the cursor on the screen of the platform so that the subjects could not correct the setting of the base of the platform.

The third assessment was power measurement. We used the Keiser Power Squat A300 device. The device generated pneumatic resistance during squats (Fig. 1). In basketball players after ACL reconstruction, we started the test with the leg that had not been operated. The load was calculated in relation to the body mass of individual subjects. In each series, the subject had three trials, and we registered the highest value of the power. The pause between the series was 90 seconds. In each consecutive series, the load was increased by 25% of the subjects' body mass. The test was finished in the moment the subject felt pain, the subject did the single leg squat incorrectly or when the generated power was lower than the power in the preceding trial.

Fig. 1. Dynamic squat test on Power Squat

The last assessment was the test of knee flexors and knee extensors strength with the use of the Biodex System 4 Pro dynamometer. The method of stabilizing the subject was in line with the standards presented in Fig. 2.

Figure 1 presents the position of the subject on the dynamometric chair. The axis of rotation of the head coincided with the axis of rotation of the knee when the head of the dynamometer was positioned horizontally.

The measurement involved flexion and extension of the knee in isokinetic conditions from full extension to 90° flexion for flexors, and extensors were assessed, e.g., from 90° flexion to full extension. In the study population, we started the test with the healthy leg. In the first three series the number of repetitions was five, and the angular velocity was ω = 240°/s, ω = 180°/s, ω = 60°/s, respectively. In the last series, the basketball players had to do 25 repetitions with the angular velocity ω = 240°/s. Table 2 presents the details. The break between each measurement was 90 seconds. We constantly motivated the subjects during the measurements in order to make them maximally involved in the task.

Fig. 2. The test of flexors and extensors of the knee joint on Biodex Multi-Joint System, Pro

Table 2. Knee flexors and knee extensors test, angular velocity and the number of repetitions

	Angular velocity ω [°/s]	Number of repetitions
1	240	5
2	180	5
3	60	5
4	240	25

We analysed the following parameters:

- PEAK TQ/BW – the peak value of torque in relation to body weight (%BW)
- TOTAL WORK,
- AVERAGE POWER,
- AGONIST/ANTAGONIST RATIO – the ratio of knee flexors torque in relation to knee extensors torque F/E.

Statistical analysis

We conducted the statistical analysis of the obtained material in the Statistica 13.1 software package.

To analyse the variables, we used both parametric and non-parametric tests. The choice of a parametric test was conditioned by meeting its basic assumptions, i.e., whether the distribution of studied variables was normal distribution. This was verified with the Shapiro–Wilk *W*-test. To assess differences in the mean level of a numerical characteristic in two population, we used the Student *t*-test for independent variables, or, alternatively, the non-parametric Mann–Whitney *U*-test. We used the Pearson correlation coefficient to determine correlations of two variables of normal distribution. For variables which did not meet the criterion of normal distribution, we calculated the Spearman's rank correlation coefficient. We set statistical significance at $p < 0.05$.

3. Results

3.1. FMS functional movement screen

We found higher values in the study population (15.10 ± 2.18) than in the clinical control group (14.6 ± 1.37). Higher results indicate worse functional results but the difference was statistically not significant ($p > 0.05$) (Table 3).

3.2. Postural stability test – one leg stance of the Biodex Balance System SD platform

We found statistically significant differences between the groups in the assessment of neuro-muscular control on the BIODEX BALANCE dynamographic platform for the following parameters. Higher results indicate worse condition.

Measurement on ustable surface for the level 4 of difficulty:

- The M/L stability parameter values for the operated leg were higher in the control group ($p = 0.044$).
- The general stability parameter values were higher values in the clinical control group for ($p = 0.011$).
- The A/P parameter values for the healthy leg in study group were higher in the clinical control group for dominant leg ($p = 0.025$).
- The M/L stability parameter values were higher for the healthy leg in the clinical control group ($p = 0.027$). Detail are presented graphically in Fig. 5.

There were no statistically significant differences in remaining parameters between the groups ($p > 0.05$) (Table 4, Fig. 3).

Table 3. FMS functional movement screen

Variables		Study group					Control group					t/Z	P
		$\bar{x}$	Me	Min	Max	SD	$\bar{x}$	Me	Min	Max	SD		
Deep squat		1.80	2.00	1.00	2.00	0.42	1.90	2.00	1.00	2.00	0.32	–0.55	0.583
Hurdle step	R	2.10	2.00	2.00	3.00	0.32	2.20	2.00	1.00	3.00	0.63	–0.50	0.617
	L	2.00	2.00	1.00	3.00	0.47	2.10	2.00	1.00	3.00	0.57	–0.40	0.690
	W	1.90	2.00	1.00	2.00	0.32	2.10	2.00	1.00	3.00	0.57	–0.92	0.357
Inline lunge	R	2.40	2.00	2.00	3.00	0.52	2.40	2.50	1.00	3.00	0.70	–0.13	0.898
	L	2.60	3.00	2.00	3.00	0.52	2.20	2.00	1.00	3.00	0.63	1.41	0.159
	W	2.30	2.00	2.00	3.00	0.48	2.20	2.00	1.00	3.00	0.63	0.27	0.786
Shoulder mobility	R	2.50	3.00	1.00	3.00	0.71	2.90	3.00	2.00	3.00	0.32	–1.50	0.134
	L	2.70	3.00	1.00	3.00	0.67	2.50	3.00	1.00	3.00	0.71	0.80	0.425
	W	2.50	3.00	1.00	3.00	0.71	2.40	2.50	1.00	3.00	0.70	0.34	0.734
ASLR active straight-leg raise	R	2.90	3.00	2.00	3.00	0.32	2.80	3.00	2.00	3.00	0.42	0.55	0.583
	L	2.90	3.00	2.00	3.00	0.32	2.70	3.00	2.00	3.00	0.48	1.04	0.301
	W	2.80	3.00	2.00	3.00	0.42	2.70	3.00	2.00	3.00	0.48	0.45	0.651
Trunk stability pushup		1.90	2.00	1.00	3.00	0.88	1.40	1.00	1.00	2.00	0.52	1.29	0.199
Rotary stability	R	1.80	2.00	1.00	2.00	0.42	1.90	2.00	1.00	2.00	0.32	–0.55	0.583
	L	2.00	2.00	2.00	2.00	0.00	1.90	2.00	1.00	2.00	0.32	0.90	0.368
	W	1.90	2.00	1.00	2.00	0.32	1.90	2.00	1.00	2.00	0.32	–0.07	0.942
Total		15.10	16.00	10.00	17.00	2.18	14.60	15.00	11.00	16.00	1.43	1.37	0.172

R – right, L – left, W – result.

Table 4. BIODEX BALANCE results

Variables			Study group		Control group		*t/Z*	*P*
			$\bar{x}$	SD	$\bar{x}$	SD		
Stable surface	O	General	2.01	0.48	2.88	1.64	–1.18	0.237
		Stability index A/P	1.48	0.52	1.90	1.00	–1.18	0.254
		Stability index M/L	1.26	0.44	1.46	0.24	–1.27	0.220
	H	General	1.76	0.51	1.85	0.61	–0.36	0.724
		Stability index A/P	1.51	0.50	1.69	0.89	–0.56	0.584
		Stability index M/L	0.70	0.37	0.68	0.31	0.13	0.897
Unstable surface	O	General	2.33	1.43	2.70	0.84	–1.67	0.096
		Stability index A/P	1.83	1.37	2.00	0.98	–0.61	0.544
		Stability index M/L	0.96	0.61	1.42	0.51	–2.01	**0.044**
	H	General	1.90	0.79	2.69	0.78	–2.54	**0.011**
		Stability index A/P	1.47	0.49	2.05	0.56	–2.44	**0.025**
		Stability index M/L	0.88	0.67	1.61	0.95	–2.21	**0.027**

Legend: O – operated; H – healthy; General index – the resultant of centre of pressure movement on the platform in the sagittal and coronal planes; Stability index A/P – the index of pressure on the platform in the sagittal plane; Stability index M/L – the index of pressure on the platform in the coronal plan.

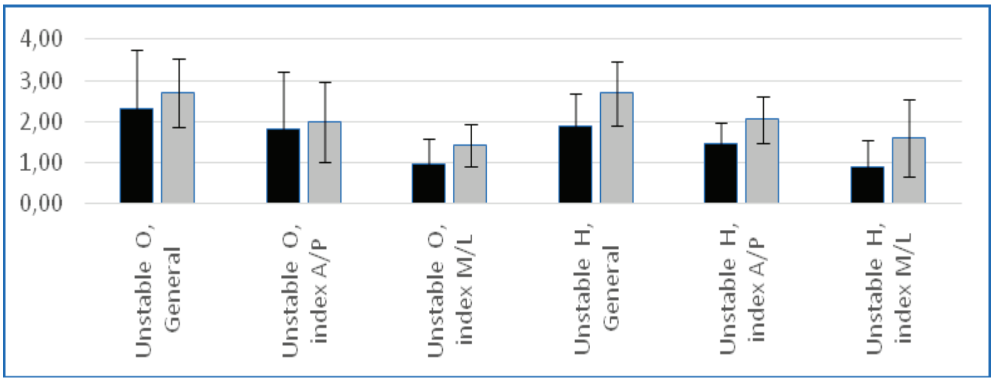

Fig. 3. Graphical presentation of stability index for unstable surface

3.3. Measurement data for the power in one leg squat

We found no statistically significant differences between the groups in the power in one leg squat ($p > 0.05$) (Tables 5 and 6).

Table 5. POWER SQUAT TEST – operated leg

Changeable load (% BW)		Study group		Control group		*T*	*P*
		$\bar{x}$	SD	$\bar{x}$	SD		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
50%	1	237.80	46.58	218.90	31.38	1.06	0.301
	2	263.10	49.05	227.00	34.17	1.91	0.072
	3	259.20	53.37	243.40	46.87	0.70	0.491
75%	1	345.10	82.22	358.70	57.41	–0.43	0.673
	2	373.40	63.13	358.60	63.49	0.52	0.608
	3	384.60	59.05	359.50	86.91	0.76	0.460
100%	1	465.60	82.58	454.60	105.19	0.26	0.798
	2	488.30	70.19	437.30	109.72	1.24	0.232
	3	499.00	110.06	459.50	106.32	0.82	0.425
125%	1	558.60	118.15	545.00	106.30	0.27	0.790
	2	559.00	138.49	498.50	131.38	1.00	0.330
	3	543.40	128.67	498.90	129.88	0.77	0.451
150%	1	630.38	122.23	646.29	98.05	–0.28	0.788
	2	646.13	120.75	587.86	89.55	1.05	0.314
	3	664.25	109.33	580.71	80.99	1.66	0.121
175%	1			725.67	164.07	–	–
	2			677.33	170.62	–	–
	3			609.67	151.79	–	–

Table 6. POWER SQUAT TEST – healthy leg

Variables		Study group		Control group		T	P
		$\bar{x}$	SD	$\bar{x}$	SD		
50%	1	261.10	48.50	226.10	51.66	1.56	0.136
	2	264.30	69.47	245.50	44.08	0.72	0.479
	3	267.00	46.37	240.80	53.27	1.17	0.256
75%	1	347.60	89.06	388.50	91.98	–1.01	0.326
	2	390.90	46.18	394.30	79.51	–0.12	0.908
	3	407.50	60.53	393.00	77.57	0.47	0.647
100%	1	504.20	67.83	483.60	123.56	0.46	0.650
	2	544.40	65.87	474.00	114.87	1.68	0.110
	3	511.10	74.84	466.80	117.60	1.00	0.328
125%	1	616.70	83.10	555.50	148.11	1.14	0.269
	2	606.90	79.51	547.00	152.40	1.10	0.285
	3	609.70	71.37	516.20	158.81	1.70	0.107
150%	1	651.63	81.82	677.86	128.96	–0.48	0.641
	2	659.88	53.36	628.14	129.55	0.64	0.536
	3	621.25	58.15	575.57	161.10	0.75	0.466
175%	1	–	–	770.00	157.87	–	–
	2	–	–	746.00	188.22	–	–
	3	–	–	699.33	226.07	–	–

3.4. Muscle strength test of flexors and extensors of the knee in isokinetic conditions with the use of the Biodex System 4 Pro dynamometer

We found statistically significantly higher values of muscle strength test of flexors and extensors for the study population in the following parameters (Table 7, Fig. 4):

– PEAK TQ/BW for the operated leg in extension ($p = 0.009$) and in flexion ($p = 0.019$),
– TOTAL WORK for the operated leg in extension ($p = 0.043$),
– TOTAL WORK in flexion for the healthy leg ($p = 0.026$) and for the operated leg ($p = 0.041$),
– AVERAGE POWER in flexion for the healthy leg ($p = 0.043$) and the operated leg ($p = 0.042$),
– AGONIST/ANTAGONIST RATIO for the healthy leg ($p = 0.043$).

In Figure 4 graphical presentation of results is shown. Although many parameters showed significant differences in favored to operated group, the differences seems not clinically significant. Study group had better results in all parameters regardless to operated or healthy knee.

We found statistically significantly higher values in the study population in data from the test in isokinetic conditions (180°/s) for the following parameters (Table 8):

– PEAK TQ/BW for the operated leg in extension ($p = 0.038$),
– PEAK TQ/BW in flexion for the healthy ($p = 0.048$) and the operated leg ($p = 0.038$).

In Figure 5 graphical presentation of results is shown. Although many parameters showed significant differences in favored to operated group, the differences were not clinically significant. Study group had better or similar results of both limbs in all parameters regardless to operated or healthy knee.

Table 7. Comparison of data from velocity and power parameters of knee flexors and extensors in isokinetic conditions (240°/s)

Variables				Study group		Control group		t/Z	P
				$\bar{x}$	SD	$\bar{x}$	SD		
EXT	PEAK TQ/BW	UIV	H	131.09	26.68	103.04	30.32	1.76	0,08
		IV	O	133.95	21.90	106.03	24.72	2.61	0,01
FLEX		UIV	H	65.23	32.21	54.29	19.32	–0.92	0,37
		IV	O	76.09	27.31	48.47	20.02	–2.58	0,02
EXT	TOTAL WORK	UIV	H	382.83	103.05	313.71	82.22	–1.66	0,12
		IV	O	395.42	101.86	308.50	74.51	–2.18	0,04
FLEX		UIV	H	242.08	89.33	153.87	71.77	–2.43	0,03
		IV	O	231.67	107.93	132.51	93.05	–2.20	0,04
EXT	AVERAGE POWER	UIV	H	157.56	50.05	128.19	38.29	1.17	0,24
		IV	O	161.54	45.58	124.92	40.04	–1.91	0,07
FLEX		UIV	H	93.37	38.90	60.06	28.90	–2.17	0,04
		IV	O	87.35	45.40	47.24	35.98	–2.19	0,04
AGONIST/ ANTAGONIST RATIO		UIV	H	61,00	10.12	52.18	7.87	–2.18	0.04
		IV	O	54,93	13.55	43.66	14.23	–1.81	0.09

Legend: EXT – extension; FLEX – flexion; PEAK TQ/BW – the peak value of torque in relation to body weight (% BW); IV – Involv; UIV – Uninvolv; H – healthy; O – operated.

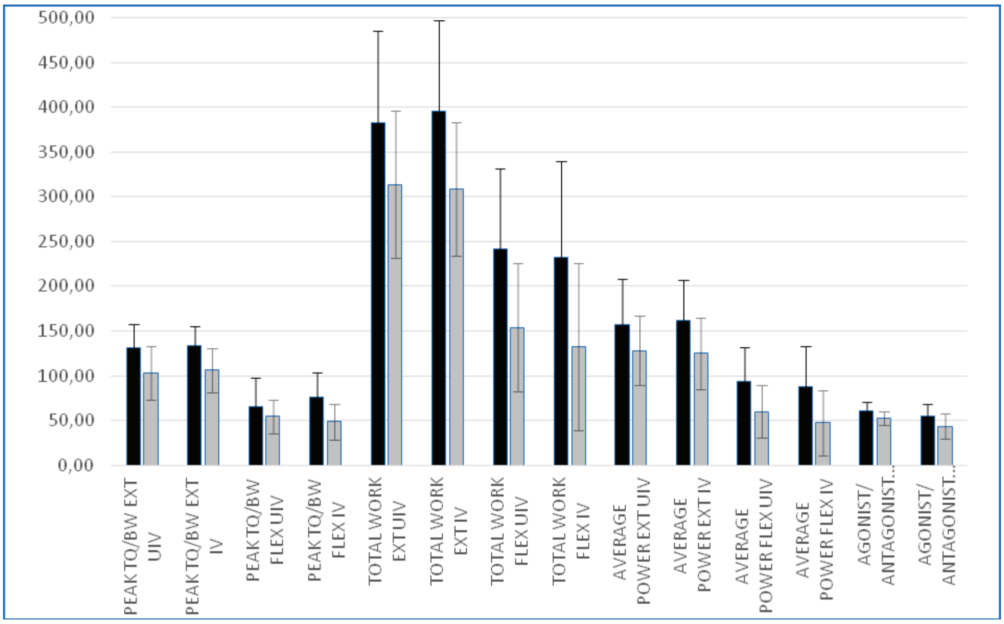

Fig. 4. Graphical presentation of velocity and power parameters of knee flexors and extensors in isokinetic conditions (240°/s)

Table 8. Comparison of measurement data of velocity and power parameters of knee flexors and extensors in isokinetic conditions (180°/s)

Variables				Study group		Control group		*t*/*Z*	*p*
				$\bar{x}$	SD	$\bar{x}$	SD		
EXT	PEAK TQ/BW	UIV	H	156.31	25.99	134.61	38.14	1.48	0,15
		IV	O	158.83	16.31	139.01	35.22	2.08	0,04
FLEX		UIV	H	95.72	16.55	77.34	21.91	2.12	0,05
		IV	O	96.67	26.55	74.80	18.00	2.08	0,04
EXT	TOTAL WORK	UIV	H	482.90	103.25	477.04	100.34	0.13	0,90
		IV	O	524.84	96.08	488.22	66.29	0.99	0,33
FLEX		UIV	H	331.56	55.55	295.53	70.80	1.27	0,22
		IV	O	325.38	97.59	275.82	71.29	1.30	0,21
EXT	AVERAGE POWER	UIV	H	170.42	40.61	164.55	31.73	0.36	0,72
		IV	O	179.00	36.23	172.60	20.58	0.49	0,63
FLEX		UIV	H	106.33	21.95	97.25	23.21	0.90	0,38
		IV	O	106.01	34.54	89.15	24.05	1.27	0,22
AGONIST/ ANTAGONIST RATIO		UIV	H	61,14	6.43	59.57	9.90	0.42	0.68
		IV	O	60,27	13.52	54.96	6.73	1.11	0.28

Legend: EXT – extension; FLEX – flexion; PEAK TQ/BW – the peak value of torque in relation to body weight (% BW); IV – Involv; UIV – Uninvolv; H – healthy; O – operated.

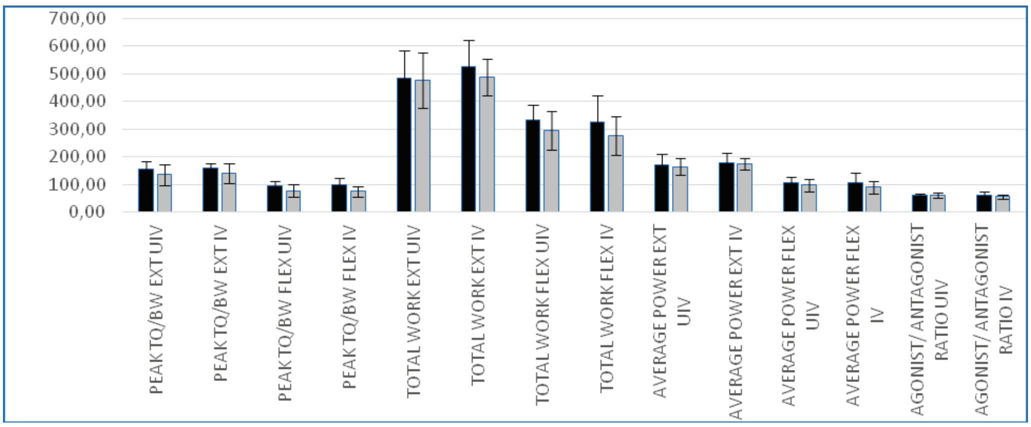

Fig. 5. Graphical presentation of velocity and power parameters of knee flexors and extensors in isokinetic conditions (180°/s)

Table 9. Comparison of measurement data of velocity and power parameters in isokinetic conditions (60°/s)

Variables				Study group		Control group		t/Z	p
				$\bar{x}$	SD	$\bar{x}$	SD		
EXT	PEAK TQ/BW	UIV	H	242.62	24.67	202.57	58.91	1.66	0.096
		IV	O	226.01	34.60	200.96	55.63	1.20	0.242
FLEX		UIV	H	139.06	16.93	117.63	33.37	1.36	0.173
		IV	O	127.51	34.76	107.85	26.11	1.43	0.169
EXT	TOTAL WORK	UIV	H	770.69	130.04	694.40	174.88	1.11	0.283
		IV	O	715.23	101.89	688.17	158.41	0.45	0.655
FLEX		UIV	H	492.41	77.54	443.87	121.98	1.06	0.302
		IV	O	457.12	109.24	422.59	120.98	0.67	0.511
EXT	AVERAGE POWER	UIV	H	108.43	19.85	99.00	21.61	1.02	0.323
		IV	O	97.74	15.75	101.67	18.82	–0.51	0.618
FLEX		UIV	H	66.04	11.70	58.28	15.15	1.28	0.216
		IV	O	59.60	16.22	55.83	10.31	1.10	0.273
AGONIST/ ANTAGONIST RATIO		UIV	H	H	4.23	58.33	9.47	0.85	0.409
		IV	O	O	14.10	54.21	6.98	–0.41	0.685

Legend: EXT – extension; FLEX – flexion; PEAK TQ/BW – the peak value of torque in relation to body weight (%BW); IV – Involv; UIV – Uninvolv; H – healthy; O – operated.

Table 10. Comparison of measurement data of velocity and power parameters in isokinetic conditions (240°/s at 25 repetitions)

Variables				Study population		Control group		t/Z	p
				$\bar{x}$	SD	$\bar{x}$	SD		
EXT	PEAK TQ/BW	UIV	H	141.61	22.38	118.26	33.97	1.82	0.086
		IV	O	140.74	16.82	120.01	30.88	2.08	0.038
FLEX		UIV	H	90.03	15.34	76.61	27.93	1.88	0.058
		IV	O	88.81	25.05	71.85	20.52	1.63	0.104
EXT	TOTAL WORK	UIV	H	1821.90	340.03	1674.22	337.87	0.97	0.343
		IV	O	1826.10	240.09	1713.12	246.12	1.03	0.312
FLEX		UIV	H	1201.16	218.38	1048.02	215.35	1.58	0.132
		IV	O	1120.80	295.08	1031.23	256.95	1.28	0.198
EXT	AVERAGE POWER	UIV	H	150.09	31.21	138.98	28.86	0.82	0.419
		IV	O	152.98	19.90	143.24	23.62	0.94	0.345
FLEX		UIV	H	93.87	20.18	82.99	18.82	1.25	0.228
		IV	O	87.59	25.31	79.52	25.10	1.02	0.307
AGONIST/ ANTAGONIST RATIO		UIV	H	H	5.70	62.15	6.76	–0.04	0.970
		IV	O	O	12.24	59.91	7.58	0.55	0.590

Legend: EXT – extension; FLEX – flexion; PEAK TQ/BW – the peak value of torque in relation to body weight (%BW); IV – Involv; UIV – Uninvolv; H – healthy; O – operated.

We did not find statistically significant differences in parameters measured in isokinetic conditions (60°/s) in knee flexors and extensors (Table 9).

We found statistically significantly higher values of parameters of knee flexors and extensors in isokinetic conditions (240°/s) with 25 repetitions in the study population for the PEAK TQ/BW parameter for the operated leg in flexion ($p = 0.038$) (Table 10).

4. Discussion

A full return to training and matches after surgical ACL reconstruction should be based on objective indices measuring the level of muscle strength, neuromuscular control and power of the treated area. The literature provides recommendations and admission criteria for the full training load [19]. In addition, according to the latest recommendations of the American association for sports medicine, professional basketball players should introduce into their training exercises that would prevent knee and cruciate ligament injuries. These exercises, involving power training, elements of plyometric training, and exercises aimed at proximal control improvement, should take approximately 20 minutes, during or after each training session [3].

The functional movement screen FMS is used in physiotherapy and in sports as a subjective set of tests that assess the quality of fundamental movement patterns. The available literature presents studies that inform of the reliability of this measurement tool in various populations [23]. Our measurements found limitations to movement patterns and compensations in the professional basketball players from both the study population and the clinical control group. The results suggest that the players are likely to have further injuries.

A study by Schneiders et al. of 209 physically active subjects aged 18 to 40 years informed of the mean screen score of 15.7 points. The subjects, regardless of sex or distortions to the locomotor system, did not show statistically significant differences [20]. In their study on American football players, Kochański et al. [12] found the mean FMS score of 14.5. They found correlations between past injuries and the screen scores. Our FMS scores show that both in the study population and in the clinical control group the female basketball players may be prone to injuries. An awareness of the deficits allows for introducing special exercises into their training. The exercises should be aimed at the dysfunctions, and they should result in minimizing the risk of injury.

The assessment of velocity and power parameters with the Biodex System 4 Pro dynamometer enables measuring of power ability of the knee flexors and extensors. To assess the locomotor system in the studied groups we chose the following parameters: the peak torque and body weight ratio (PQ/BW %), total work, average power, and the antagonist muscle ratio, i.e., the flexors to extensors ratio F/E. The measurements were taken at various angular velocities. The literature provides normative values for certain measurement conditions. For measurements in isokinetic conditions with the angular velocity of $\omega = 60$ °/s the norms for the peak torque to body weight index for the knee extension pattern take values from the range of 238÷283 Nm/BW [15]. Female basketball players from the study population had mean values in the range of 226.01 ± 34.60 Nm/BW for the operated leg, and 242.62 ± 24.67 Nm/Bw for the healthy leg. In the clinical control group the values were lower for the non-dominant leg and they were 200.96 ± 55.63 Nm/Bw, and for the dominant leg they were 202.57 ± 58.91 Nm/BW. Only the results of the studied population, for the healthy leg, were within the normative range quoted above. For the parameter of peak torque in relation to body weight for the knee flexion pattern the normative range is 145÷173 Nm/BW [15]. In the studied population, the mean value was 127.51 ± 34.76 for the operated leg, and 139.06 ± 16.93 for the healthy leg. The clinical controls had lower values for the non-dominant leg, 107.85 ± 26.11, and 117.63 ± 33.37 for dominant leg. For the measurement of peak torque to body weight ratio at the angular velocity of $\omega = 180$ °/s the normative range is 149÷194 Nm/BW [15]. The study population had mean values of 158.83 ± 16.31 for the operated leg and 156.31 ± 25.99 for the healthy leg. The clinical controls had significantly lower values. For the non-dominant leg the values were 139.01 ± 35.22 Nm/BW, and for the dominant leg they were 134.61 ± 38.14. The study population athletes had much better results, and their results are within the normative range. There was also a statistically significant difference between both groups in results for the operated leg ($p = 0.038$). The comparison of results for the study population between the operated and non-operated leg showed that mean values for the operated leg are higher than mean values for the healthy leg. This may prove that the training aimed at restoring velocity and power parameters after ACL reconstruction was more efficient.

The value of the ratio of the power of the flexors to the power of the extensors F/E that we found in the study allows for estimation of risk of injury. The mean values for the study population at the angular velocity of $\omega = 60$ °/s were 56.17 ± 14.10 for the operated leg and 56.98 ± 4.23 for the healthy leg. In the clinical control group the results were similar, with values of 54.21 ± 6.98 for the dominant leg and 58.33 ± 9.47 for non-dominant leg. According to the literature, the values should fall within the range of approximately 60 to 70. The basketball players had results that were slightly below this norm. Michnik et al. [18] studied female volleyball players. Their subjects had lower results than female basketball players from our study, i.e., 49.2 ± 3 for the operated leg and 44.5 ± 6.2 for the healthy leg. Our results show that basketball players had stronger knee extensors. In their studies, Bittencourt et al. [5] and Dvorak et al. [10] found a deficit of knee flexors in volleyball players, which was 51% and 52%, respectively.

Values of the F/E index at angular velocity of ω =180 °/s in our study population were 60.27 ± 13.52 for the operated leg and 61.14 ± 6.43 for the healthy leg. For the controls, it was 54.96 ± 6.73 for dominant and 59.57 ± 9.90 for non-dominant, respectively. The mean values of our basketball players are significantly below the norm provided by the literature, which is 76. This confirms that the knee extensors are stronger than knee flexors. Our results are in line with results of other authors quoted above. Measurements by Wilk et al. [26], at the angular velocity of ω = 180 °/s showed that there was a 30% loss of knee flexors and knee extensors strength in young female players. This deficit may result in injuries and strains.

Our study aimed to assess neuro-muscular control. We used the Biodex Balance System dynamographic platform. For neuro-muscular assessment, the system relies on control on stable and unstable surface. Our results show that in the clinical control group the general index, the A/P stability index and M/L stability index was better compared to study population. This means that neuro-muscular control is weaker in players after ACL reconstruction. A comparison of operated and healthy leg results for the study population showed that the operated leg had higher results. This mean that despite rehabilitation, motor control is lower than in the clinical control group.

Earlier comparative studies on football players after ACL reconstruction and healthy football players conducted by Alonso et al. [1] found that moving the centre of gravity is lower in football players after reconstruction than in healthy football players. Moreover, they observed that higher deviation values are found in healthy legs of footballers after ACL reconstruction in comparison to the operated leg. Our study seems to confirm this observation. However, Bączkowicz et al. [4] in their study found that stability parameter values are higher in the operated leg than in the healthy leg or in the clinical control group, which translates into deficit of neuro-muscular control, possibly predisposing towards further injury.

The discrepancy of study results may be related to the differences of study methodology and the time span between ACL reconstruction and the measurement.

Measuring power in single leg squat was one of the elements of our complex assessment. In team games, single leg load is a common pattern, e.g., in layup, jump and landing for rebound, changing direction. The more power generated, the higher a player can jump. The measurement in the study population showed that the power values related to body weight were lower on the side of the operated leg. For the load of 125% body weight, both legs were stronger in the study population than in the control group. Yet after this load was exceeded, the clinical control group had higher power values. The study population players were not able to perform the single leg squat with load of 175% of their body weight.

Shelds et al. [22] found that training with single leg squat strengthens muscle groups of lower limbs and improves coordination of the muscles engaged in the pattern. The positive effects lead to increased dynamic control of the knee.

The issue of rehabilitation after injury of anterior cruciate ligament in basketball players is vast. This is because the most common injury in this sport is leg injury. Leg injuries constitute 65% of total injuries in basketball, and anterior cruciate ligament tear is 1% of all injuries [9]. Many authors believe that females are more prone to this injury than men [2], [10], [19].

There are numerous protocols for physiotherapy after ACL reconstruction. None of them, however, guarantees a full recovery to the state from before the injury. The process of rehabilitation has to be adjusted individually to each player, their needs and to additional factor, e.g., their motivation [13]. Physiotherapy after ACL reconstruction takes 6 to 12 months, on average. Kvist et al. [14] concluded that considerable number of sports people do not return to professional sport after the injury. This is caused by the fear of repeated injury, long lasting rehabilitation and motor deficits that are common after ACL reconstruction.

Our study presents crucial data on the motor ability of basketball players, both after ACL reconstruction and with healthy ACL. The measurement data show the need of training individually adapted to diagnosed deficit. It is important to note that the subjects after ACL reconstruction did not regain the motor level of required standard, which may predispose them towards repeated injury.

In the interviews we conducted with the players, the players pointed to the difficulties in accessing complex medical tests that would enable the monitoring of the physiotherapeutic process and aiming the motor training at their particular needs after ACL reconstruction. In collecting information on the completed rehabilitation it was difficult to ascertain the details of the conducted treatment (protocol). This was why we did not include this aspect in our study.

Value of the study. The results of the complex assessment of athletes showed that both healthy players and those after ACL reconstruction have numerous functional deficits. The deficits may lead to further injuries.

5. Conclusions

The level of motor and functional recovery in female basketball players after ACL reconstruction is insufficient and does not meet the criteria described for the safe return to full training loads. The motor preparation of female basketball players in the clinical control group is poorer than what is accepted in the available literature. There is a well-grounded need to include motor parameter monitoring in the process of physiotherapy after ACL reconstruction.

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