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original research

Explosive Strength Imbalances in Professional Basketball Players

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Context: Despite the high rate of lower limb injuries in basketball players, studies of the dominant-limb effect in elite athletes often neglect injury history.

Objective: To determine lower limb explosive-strength asymmetries in professional basketball players compared with junior basketball players and control participants.

Design: Cohort study.

Setting: Academic medical institution.

Patients or Other Participants: 15 professional basketball players, 10 junior basketball players, and 20 healthy men.

Main Outcome Measure(s): We performed an isokinetic examination to evaluate the knee extensor (Ext) and flexor (Fl) concentric peak torque at $60^\circ \cdot s^{-1}$ and $240^\circ \cdot s^{-1}$ and (Fl only) eccentric peak torque at $30^\circ \cdot s^{-1}$ and $120^\circ \cdot s^{-1}$. Functional evaluation included countermovement jump, countermovement jump with arms, 10-m sprint, single-leg drop jump, and single-leg, 10-second continuous jumping. Variables were compared among groups using analysis of variance or a generalized linear mixed model for bilateral variables.

Results: The 2 groups of basketball players demonstrated better isokinetic and functional performances than the control group did. No differences in functional or relative isokinetic variables were noted between professional and junior basketball players. Professional players with a history of knee injury failed to reach normal knee extensor strength at $60^\circ \cdot s^{-1}$. Knee Ext ($60^\circ \cdot s^{-1}$) and Fl (eccentric $120^\circ \cdot s^{-1}$) torque values as well as 10-second continuous jumping scores were higher in those professional players without a history of knee injury than those with such a history. Compared with the group without a history of knee injury, the group with a history of knee injury maintained leg asymmetry ratios greater than 10% for almost all isokinetic variables and more than 15% for unilateral functional variables.

Conclusions: The relative isokinetic and functional performances of professional basketball players were similar to those of junior players, with no dominant-side effect. A history of knee injury in the professional athlete, however, was reflected in bilateral isokinetic and functional asymmetries and should be considered in future studies of explosive strength.

Key Words: isokinetic activity, muscular balance, knee injuries

Key Points

- Professional and junior-level basketball players displayed similar isokinetic knee profiles and functional performances.
- However, a history of knee injury in the professional players was associated with bilateral isokinetic and functional asymmetries.
- Standardized criteria to assess readiness for return to sport are needed.

Basketball is becoming increasingly popular in many countries and is played worldwide by more than 450 million people.[1] At the professional level, numerous tests and training programs are being used to monitor the cardiovascular[2] and athletic[3] performances of players. The results of these evaluations are used to adjust training techniques in an attempt to prevent traumatic and overuse injuries.

Zakas et al[4] showed that compared with players in lower divisions, professional basketball players did not produce higher quadriceps or hamstrings peak torque values relative to body weight. Theoharopoulous and Tsitskaris[5] and Rahnama et al[6] suggested that the training necessary to reach the professional level creates a dominant lower limb in basketball and soccer players. Nevertheless, the literature includes contradictions, and many other authors[7–11] found no differences in peak torque outputs, regardless of dominance or sport activity level.

Because basketball is a contact pivot sport, its associated injury rate is not negligible. Messina et al[12] estimated that male high school basketball players sustained injuries at a rate of 0.56 per season, leading to 16.9 injuries per 1000 hours of game exposure, whereas National Basketball Association players displayed an overall game injury rate of 19.3 per 1000 athlete-exposures.[13] The joints at most risk are the knee (19.1% of all injuries, 13% of game injuries), the ankle (16.9% of all injuries, 20.9% of game injuries), the lumbosacral spine (9.0% of all injuries, 7.2% of game injuries), and the feet and toes (7.9% of all injuries, 5.0% of game injuries).[13] It is interesting that many injuries to the lower limb alter muscle performance, which can be identified by isokinetic and functional tests.[7,14–20]

A past history of injury rarely is taken into consideration when investigating muscle strength profiles in athletes. Subjectively, most authors seem to regard active, top-level athletes as completely healthy and recuperated from any significant past injury. Yet, trying to specify clear criteria for a return to competition and secondary injury prevention is one of the most active fields of sports medicine research today. Recognizing elite athletes with muscular

Table 1. Descriptive Anthropometric and Biometric Data (Mean ± SD)

	Group				
	Professional Players				
Factor	With History of Knee Injury	Without History of Knee Injury	Junior Players	Control	*P* Value
Age, y	28.3 ± 6.3^{a,b}		18.9 ± 1.2^{c}	23.5 ± 3.3^{b,c}	<.009
	31.0 ± 5.5	27.0 ± 6.5			.26
Height, cm	198.0 ± 8.4^{a,b}		192.7 ± 7.4^{b}	179.8 ± 6.7^{a,b}	<.0001
	194.0 ± 9.6	200.0 ± 2.9			.20
Mass, kg	95.9 ± 8.6^{a,b}		81.1 ± 8.2^{a}	73.0 ± 11.6^{b}	<.0001
	98.1 ± 2.7	94.9 ± 6.3			.51
Fat, %	18.9 ± 3.8		14.3 ± 3.0	15.6 ± 5.9	.07
	22.7 ± 2.2	17.1 ± 2.9			.002

[a] Difference between professional players and junior players.

[b] Difference between professional players and control group.

[c] Difference between junior players and control group.

imbalances and identifying a normal adaptation to sport versus a pathologic situation related to previous injuries is very important in understanding and using muscular testing in elite athletes.

The purpose of our study was to determine whether professional basketball players developed differences between the dominant and nondominant limbs in comparison with junior players and control participants. Furthermore, we wanted to find out whether these differences in professional players were related to a history of knee injury.

METHODS

Participants

The 15 professional basketball players were part of 2 First Division teams participating in European Cup competitions. All had been practicing at least 14 hours a week for the last 4 seasons and were declared able to engage in competition-level basketball by the team physicians at the time of testing. The 10 junior players randomly chosen from 1 team have had 2 to 3 practices a week for at least 4 years. The 20 male control volunteers were recruited from a college community. The study was approved by the ethics committee of the university, and informed consent was obtained from all 45 male volunteers.

We evaluated the medical histories of all participants to detect any past injuries that could influence their performances. Of all the volunteers, we identified 5 professional players with significant past knee injuries that were confirmed by clinical and imaging tests and resulted in the loss of at least 4 weeks of practice or competition time. Three had suffered severe chondral knee lesions, 2 of which required arthroscopic debridement and shaving. One player underwent arthroscopic shaving of a lateral meniscus lesion during the preceding season. The fifth player had a bone-patellar tendon-bone autograft anterior cruciate ligament (ACL) reconstruction 9 years earlier.

Descriptive anthropometric and biometric data of all participants are shown in Table 1. We used bioelectric impedance analysis (model T100; Tanita Corp, Arlington Heights, IL) to calculate body fat percentages. Segal[21] reviewed the use of bioelectric impedance analysis in athlete populations and concluded that it provides an acceptable estimate of body composition with, however, an apparent racial bias, overestimating fatness by about 4% in blacks. Most bioelectric impedance equations do not adjust for racial differences.[21]

Testing Procedures

Isokinetic testing was performed to assess hamstrings and quadriceps muscle function using a Cybex Norm (Henley Corp, Sugarland, TX). All measurements were preceded by a standardized warm-up consisting of peddling on an ergometric bicycle (75 to 100 W) and stretching exercises for the hamstrings and quadriceps muscles. The participant was seated on the dynamometer (with 105° of coxofemoral flexion) with the body stabilized by several straps around the waist, thigh, and chest to avoid compensatory movement. Knee range of motion was fixed at 100° of flexion from active maximum extension. The gravitational factor of the dynamometer's lever arm and lower leg segment ensemble was calculated by the dynamometer and automatically compensated for during the measurements. Familiarization with the dynamometer was provided in the form of warm-up isokinetic repetitions at 120°·s^{-1} angular speed. Verbal encouragement was given during the test, but visual feedback was not provided. Concentric (Con) peak torque (PT) of hamstrings and quadriceps muscles was measured at 60°·s^{-1} and 240°·s^{-1}. Afterward, the flexor muscles were subjected to eccentric (Ecc) angular speeds of 30°·s^{-1} and 120°·s^{-1}. Isokinetic testing was performed by one investigator (D.M.).

The resulting analysis included the absolute and relative peak torque (Nm and Nm·kg^{-1}, respectively) as well as conventional and mixed[14] (Ecc flexors at 30°·s^{-1} versus Con quadriceps at 240°·s^{-1}) flexors-quadriceps PT ratios. The asymmetries determined in the bilateral comparisons were expressed in percentages. The nature of the deficiency was characterized using statistically selected cutoffs[15]: concentric quadriceps relative PT of less than 2.09 Nm·kg^{-1} at 60°·s^{-1}, flexors relative PT of less than 1.14 Nm·kg^{-1} at 60°·s^{-1} (Con) and less than 1.41 Nm·kg^{-1} at 30°·s^{-1} (Ecc), bilateral differences of 15% or more, conventional ratios less than 0.47, and mixed ratios less than 0.80. This protocol has been validated and published in other studies from our laboratory.[15,16] In agreement with the literature, a limb symmetry index of less than 90% also was considered abnormal for PT.[17]

The anaerobic power testing session was conducted indoors by a physical therapist (C.L.) and 1 physician (M.S.) on another day. Before testing, each participant underwent a standardized warm-up. Ten minutes of stationary bicycling (75 to 100 W) were followed by supervised stretching of the hamstrings, quadriceps, and triceps surae muscles. The volunteers first performed a countermovement jump (CMJ) with the hands on the hips, followed by a CMJ with arm swing. They were then asked to execute a single-leg drop jump (DJ) from a 20-cm height. (The protocol of the final jumping test conducted is the same as the 10-second vertical jump described by Petschnig et al.[18]) During both of these tests, participants were encouraged to react as quickly as possible on the floor, to jump as high as possible, and always to land on the same foot. They also were instructed to keep their hands on their hips to eliminate use of the hands in generating momentum.

These tests[22] were evaluated using the Optojump system (Microgate, Bolzano, Italy), a dual-beam infrared optical device. The Optojump measures contact and flight times during a series of jumps. Flight time was used to calculate height of the rise of the body's center of gravity:

$$\text{height} = \frac{g \bullet T_v^2}{8}$$

The second part of this session consisted of a 10-m sprint. Starting position (rearfoot toes at the site of the heel of the front foot) was standardized and staggered; to eliminate reaction time, the volunteers started when ready without any signal. Sprint times were measured using photoelectric cells positioned at 60 cm (at the starting line) and at chest height (about 150 cm) at the finish line to avoid premature activation by the upper limbs.

Participants performed 3 trials for each test, except for the 10-second vertical jump test, and the best performance was used for data analysis. Height (CMJ, CMJ with arms free, and DJ), average height (10-second vertical test), and sprint time were the factors analyzed. For this study, the dominant limb of basketball players was defined as the one used preferably in a single-legged jump, as described by Theoharopoulous and Tsitskaris.[5] To calculate limb symmetry (LSI), the following formulas were used:

$$\text{LSI} = \left(1 - \frac{\text{nondominant limb}}{\text{dominant limb}}\right)100$$

or

$$\text{LSI} = \left(1 - \frac{\text{limb with injury history}}{\text{limb without injury history}}\right)100$$

The first formula was used for all participants without a history of knee injury, whereas the second formula was applied to professional players with such a knee injury history. An LSI score of more than 15% was considered abnormal.[18,19,23]

Data Analysis

Results were expressed as mean ± SD. Variables were compared among the 3 groups with analysis of variance. Each group was compared with the other using Scheffé simultaneous tests. For bilateral variables (ie, dominant and nondominant limbs), a general linear mixed model (GLMM) was applied to test the effect of the group by taking the 2 limbs into account. Results were considered significant at the 5% critical level. Data analysis was carried out using the SAS statistical package (version 9.1 for Windows; SAS Institute Inc, Cary, NC).

RESULTS

Professional basketball players with a history of knee injury tended to be older, shorter, and heavier than uninjured players, but only fat percentage (22.7% versus 17.1%) achieved statistical significance (Table 1).

In general, the professional group had higher absolute PT values during isokinetic testing than the other 2 groups had (Table 2). However, these differences became negligible when body mass was taken into consideration (Table 3). At $60° \cdot s^{-1}$ concentric extensor contraction, the professional group revealed asymmetry above the 10% clinically significant cutoff point.

The 2 basketball groups recorded better performances than the control group for several functional tests (CMJ with arms, DJ, 10-second jump height), but none of the functional tests (Table 4) demonstrated a difference between the basketball groups. Yet the professional players displayed greater leg asymmetry in the DJ (12%), as noted in Table 4. Even though this asymmetry did not reach 15%, it was higher than in the junior and control groups. The 10-m sprint times were comparable among the 3 groups.

As seen in Table 5, players with a history of knee injury failed to achieve normal knee extensor strength at $60° \cdot s^{-1}$ (2.01 ± 0.60 $Nm \cdot kg^{-1}$); the lower normal limit defined by previous authors[15] for a general sedentary population is 2.09 $Nm \cdot kg^{-1}$. In comparison, the knee extensors of the dominant leg of the players without a history of knee injury reached 3.19 ± 0.54 $Nm \cdot kg^{-1}$ ($60° \cdot s^{-1}$). Using the GLMM analysis, we found that the group with the knee injury history performed worse with the knee Fl and Ext at $60° \cdot s^{-1}$, whereas their concentric Fl to Ext ratios were higher than those of the players without a knee injury history. The group with the knee-injury history maintained leg asymmetry ratios above 10% for all isokinetic values except knee Ext at $240° \cdot s^{-1}$ and mixed Fl Ecc/Ext Con ratio.

Bilateral functional tests (CMJ and CMJ with arms) as well as sprint results (1.91 ± 0.13 seconds versus 1.90 ± 0.08 seconds) were comparable in both groups (Table 6). Unilateral jump tests, however, demonstrated greater asymmetry in the group with the knee-injury history: DJ (18.4% versus 8.9%) and 10-second height (20.5% versus 5.5%). The GLMM analysis confirmed that players without a knee-injury history achieved globally better results in the 10-second jump test. Table 7 demonstrates the most relevant individual isokinetic and functional asymmetries in relation to injury history.

DISCUSSION

Analysis of absolute isokinetic concentric PT values showed better performances for the professional players than for the junior players (Fl PT at $60° \cdot s^{-1}$ and $240° \cdot s^{-1}$, Ext PT at $240° \cdot s^{-1}$) and control group (all Fl and Ext PT).

Table 2. Absolute Isokinetic Testing in the Professional Players, Junior Players, and Control Group (Mean ± SD)

Measurement	Group			*P* Value
	Professional Players (n = 15)	Junior Players (n = 10)	Control (n = 20)	
Knee flexors				
60°·s^{-1}, dominant limb, Nm	182.1 ± 32.5[a,b]	151.7 ± 25.2	121.4 ± 20.2	< .0001[c]
60°·s^{-1}, nondominant limb, Nm	166.5 ± 30.7	139.1 ± 17.7	122.6 ± 26.2	
60°·s^{-1}, bilateral difference, %	8.2 ± 11.3	7.4 ± 9.3	−2.6 ± 14.9	.04
240°·s^{-1}, dominant limb, Nm	117.8 ± 21.0[a,b]	95.1 ± 18.5	82.5 ± 22.0	< .0001[c]
240°·s^{-1}, nondominant limb, Nm	109.3 ± 18.6	89.1 ± 16.9	83.4 ± 14.9	
240°·s^{-1}, bilateral difference, %	6.5 ± 12.3	5.6 ± 10.5	−1.7 ± 9.5	.1
Knee extensors				
60°·s^{-1}, dominant limb, Nm	286.1 ± 56.2[b]	251.3 ± 25.2[d]	193.8 ± 42.9	< .0001[c]
60°·s^{-1}, nondominant limb, Nm	251.9 ± 58.2	242.3 ± 31.9	196.3 ± 41.8	
60°·s^{-1}, bilateral difference, %	11.3 ± 17.4	3.6 ± 8.8	−0.2 ± 10.8	.06
240°·s^{-1}, dominant limb, Nm	176.3 ± 35.5[a,b]	136.3 ± 16.9	124.5 ± 27.0	<.0001[c]
240°·s^{-1}, nondominant limb, Nm	166.2 ± 32.1	142.3 ± 11.8	124.9 ± 24.4	
240°·s^{-1}, bilateral difference, %	4.9 ± 12.0	-5.3 ± 11.0	1.2 ± 11.0	.1
Ratio				
Flexor/extensor, 60°·s^{-1}, concentric, dominant limb	0.65 ± 0.12[a]	0.60 ± 0.07	0.64 ± 0.09	.06[c]
Flexor/extensor, 60°·s^{-1}, concentric, nondominant limb	0.68 ± 0.13	0.58 ± 0.06	0.64 ± 0.12	
Flexor/extensor, 60°·s^{-1}, bilateral difference	-7.2 ± 23.4	3.5 ± 11.0	−4.3 ± 23.3	.46
Knee flexors (eccentric)				
30°·s^{-1}, dominant limb, Nm	225.6 ± 37.7[b]	200.9 ± 50.0[d]	151.7 ± 29.9	<.0001[c]
30°·s^{-1}, nondominant limb, Nm	204.1 ± 32.4	206.3 ± 42.6	146.3 ± 31.0	
30°·s^{-1}, bilateral difference, Nm	8.9 ± 8.8[a]	−4.3 ± 12.0	1.8 ± 13.3	.03
120°·s^{-1}, dominant limb, Nm	230.0 ± 37.6[b]	206.1 ± 42.6[d]	156.9 ± 27.2	<.0001[c]
120°·s^{-1}, nondominant limb, Nm	210.7 ± 40.0	205.4 ± 29.1	147.2 ± 28.0	
120°·s^{-1}, bilateral difference, %	7.7 ± 14.3	−1.3 ± 12.3	3.9 ± 14.3	.29
Mixed ratio				
Flexor/extensor, dominant limb	1.31 ± 0.27[a]	1.47 ± 0.29[d]	1.23 ± 0.25	.009[c]
Flexor/extensor, nondominant limb	1.26 ± 0.29	1.44 ± 0.22	1.19 ± 0.27	
Flexor/extensor, bilateral difference	2.7 ± 15.1	0.4 ± 12.3	−0.5 ± 20.1	.86

[a] Difference between professional players and junior players.
[b] Difference between professional players and control group.
[c] *P* value is for dominant versus nondominant limb among the groups.
[d] Difference between junior players and control group.

Table 3. Relative Isokinetic (Nm·kg^{-1}) Testing in the Professional Players, Junior Players, and Control Group (Mean ± SD)

Measurement	Group			*P* Value[a]
	Professional Players (n = 15)	Junior Players (n = 10)	Control Group (n = 20)	
Knee flexors/kg				
60°·s^{-1}, dominant limb	1.90 ± 0.29[b]	1.93 ± 0.28[c]	1.67 ± 0.20	.02
60°·s^{-1}, nondominant limb	1.74 ± 0.30	1.77 ± 0.16	1.68 ± 0.20	
240°·s^{-1}, dominant limb	1.23 ± 0.19	1.22 ± 0.26	1.14 ± 0.14	.56
240°·s^{-1}, nondominant limb	1.14 ± 0.20	1.14 ± 0.24	1.14 ± 0.10	
Knee extensors/kg				
60°·s^{-1}, dominant limb	3.00 ± 0.61[d]	3.20 ± 0.23[c]	2.66 ± 0.40	.006
60°·s^{-1}, nondominant limb	2.65 ± 0.68	3.09 ± 0.38	2.69 ± 0.43	
240°·s^{-1}, dominant limb	1.85 ± 0.39	1.75 ± 0.26	1.72 ± 0.22	.52
240°·s^{-1}, nondominant limb	1.75 ± 0.38	1.82 ± 0.16	1.71 ± 0.22	
Knee flexors/kg, eccentric				
30°·s^{-1}, dominant limb	2.36 ± 0.39[b]	2.54 ± 0.52[c]	2.10 ± 0.39	.0001
30°·s^{-1}, nondominant limb	2.14 ± 0.33	2.61 ± 0.39	2.01 ± 0.33	
120°·s^{-1}, dominant limb	2.40 ± 0.38[b,d]	2.62 ± 0.49[c]	2.16 ± 0.31	<.0001
120°·s^{-1}, nondominant limb	2.21 ± 0.45	2.61 ± 0.25	2.03 ± 0.33	

[a] *P* value is for dominant versus nondominant limb among the groups.
[b] Difference between professional players and control group.
[c] Difference between junior players and control group.
[d] Difference between professional players and junior players.

Table 4. Results of Functional Tests in the Professional Players, Junior Players, and Control Group (Mean ± SD)

	Group			
Test	Professional Players (n = 15)	Junior Players (n = 10)	Control (n = 20)	*P* Value
Countermovement jump, cm	40.5 ± 5.7	41.8 ± 5.8	36.5 ± 4.9	.03
With arms	48.7 ± 5.3[a]	50.7 ± 7.9[b]	43.2 ± 5.3	.007
10-m sprint, s	1.91 ± 0.09	1.89 ± 0.08	1.91 ± 0.06	.81
Drop jump				
Dominant limb, cm	28.4 ± 5.5[a]	25.2 ± 4.2[b]	20.5 ± 3.7	<.0001
Nondominant limb, cm	25.0 ± 5.3	25.5 ± 4.3	21.2 ± 3.1	<.0001
Bilateral difference, %	12.0 ± 7.9[a,c]	−1.4 ± 7.5	−4.1 ± 11.6	<.0001
10-s height				
Dominant limb, cm	20.6 ± 4.5[a]	19.3 ± 3.7[b]	14.0 ± 2.7	<.0001
Nondominant limb, cm	18.6 ± 5.0[a]	18.6 ± 3.6[b]	13.3 ± 2.2	<.0001
Bilateral difference, %	10.5 ± 12.4	3.4 ± 7.1	3.2 ± 15.6	.24

[a] Difference between professional players and junior players.

[b] Difference between junior players and control group.

[c] Difference between professional players and control group.

Yet when body mass was taken into account, the differences between the professional and junior players disappeared. Previous investigators published similar observations about basketball[4] and soccer[24,25] players. Our relative hamstrings and quadriceps PT values were in agreement with those of other researchers investigating junior and professional athletes in different sports.[4,8,25–30] Also, conventional Fl Con/Ext Con as mixed Fl Ecc/Ext Con ratios remained above statistical cutoffs and were comparable among our groups. In contrast to other studies,[25,28,30] only Cometti et al[24] showed an effect of age or level on hamstrings to quadriceps ratios in soccer and basketball players.

We believe that the sport of basketball and, in particular, the global strength and flexibility training performed by most players, does not create an imbalance between knee Fl and Ext muscle groups. The absolute and relative eccentric flexor PTs measured in professional and junior players were higher than in the control group. Even though relative PT values cannot discriminate between professional and junior players, higher absolute force production in taller and heavier athletes certainly contributes to their competitive advantage over junior players.

Similar to the relative isokinetic performances, none of the functional tests discriminated between the professional and junior players. To our knowledge, no recent authors have compared functional tests of basketball players at different levels, and we found few studies of functional tests in elite basketball players. Maffiuletti et al[31] noted slightly better results in the CMJ for experienced basketball players using the Bosco mat (51.0 to 53.0 cm). Malatesta et al[32] investigated regional volleyball players, using the Ergojump-Bosco system, and determined CMJ performances of approximately 49 cm. For other regional volleyball players, using the Optojump system, however, Maffiuletti et al[33] recorded CMJ and CMJ-with-arms heights of only approximately 40 and 47 cm, respectively. Part of the

Table 5. Relative Isokinetic Testing in Professional Players With or Without a History of Knee Injury (Mean ± SD)

		With History of Knee Injury (n = 5)		Without History of Knee Injury (n = 10)			
Variable	Measurement	Uninjured Limb	Injured Limb	Dominant Limb	Nondominant Limb	Group/Injury *P* Value	Limb *P* Value
Knee flexion strength							
Concentric	$60^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	1.82 ± 0.34	1.54 ± 0.29	1.94 ± 0.27	1.84 ± 0.27	.08	.11
	Bilateral difference, %	14.4 ± 16.2		5.1 ± 7.0		.14	
	$240^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	1.20 ± 0.14	1.07 ± 0.22	1.25 ± 0.21	1.18 ± 0.19	.31	.23
	Bilateral difference, %	10.2 ± 17.0		4.7 ± 9.8		.43	
Eccentric	$30^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	2.40 ± 0.22	2.11 ± 0.11	2.34 ± 0.46	2.15 ± 0.41	.96	.12
	Bilateral difference, %	−17.4 ± 38.3		−2.1 ± 10.7		.24	
	$120^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	2.27 ± 0.25	1.89 ± 0.34	2.47 ± 0.42	2.37 ± 0.41	.036	.13
	Bilateral difference, %	16.1 ± 17.0		3.5 ± 11.5		.11	
Knee extension strength							
Concentric	$60^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	2.60 ± 0.59	2.01 ± 0.60	3.19 ± 0.54	2.97 ± 0.46	.0024	.072
	Bilateral difference, %	21.4 ± 25.9		6.3 ± 9.5		.12	
	$240^\circ\cdot s^{-1}$, $\text{Nm}\cdot\text{kg}^{-1}$	1.74 ± 0.36	1.62 ± 0.41	1.90 ± 0.41	1.82 ± 0.37	.26	.49
	Bilateral difference, %	7.6 ± 14.5		3.6 ± 11.2		.56	
Knee flexion-extension strength ratio, $60^\circ\cdot s^{-1}$		0.72 ± 0.18	0.80 ± 0.14	0.61 ± 0.06	0.62 ± 0.08	.005	.33
	Bilateral difference, %	−17.4 ± 38.3		−2.1 ± 10.7		.24	
Mixed flexion-extension strength ratio		1.43 ± 0.38	1.39 ± 0.46	1.25 ± 0.19	1.20 ± 0.16	.0024	.072
	Bilateral difference, %	2.1 ± 20.0		3.1 ± 13.4		.91	

Table 6. Functional Testing in Professional Basketball Players With or Without a History of Knee Injury (Mean ± SD)

Test	With History of Knee Injury (n = 5)	Without History of Knee Injury (n = 10)	*P* Value
Countermovement jump, cm	38.4 ± 8.0	41.6 ± 4.3	.32
With arms	47.6 ± 7.3	49.3 ± 4.3	.59
10-m sprint, s	1.91 ± 0.13	1.90 ± 0.08	.91
Drop jump			
Dominant limb, cm	27.0 ± 7.3	29.1 ± 4.6	.16[a]
Nondominant/history	22.3 ± 7.2	26.4 ± 3.9	
Bilateral difference, %	18.4 ± 7.8	8.9 ± 6.1	.02
10-s height			
Dominant limb, cm	18.9 ± 6.1	21.5 ± 3.6	.046[a]
Nondominant/history	15.2 ± 5.4	20.3 ± 4.0	
Bilateral difference, %	20.5 ± 7.8	5.5 ± 11.3	.02

[a] *P* value is for dominant versus nondominant limb among the groups.

disparity observed could thus result from the different measurement techniques.

The 10-m sprint and CMJ performances recorded by our basketball players are similar to those of 2 French groups[24,25] investigating soccer players: Junior or amateur players performed better in different jump tests and 10-m sprints than professional players did. On the other hand, Keogh et al[34] demonstrated better results in higher-level female field hockey players on a combination of anthropometric (percentage of body fat), physiologic (10-m sprint, vertical and long jumps, aerobic power), and skill-related tests. Furthermore, Baker[35] established that strength in the upper body (bench press throw) and lower body (jump squat with 20 kg) was higher in elite professional rugby players than in college-aged rugby players and that 1-repetition maximum bench press was related to achievement levels in rugby league players. We can, therefore, suppose that even yearlong basketball practice does not represent a sufficient training stimulus to develop superior jumping and sprinting abilities in professional players. Future authors will need to learn whether a combination of more basketball-specific and upper body strength tests is able to differentiate among basketball players at different levels. The absence of differences between professional and junior players may also be due to other factors not measured in our study, which could include technical skills, decision making, and intrinsic talent.

Few authors have evaluated athletes using unilateral functional tests. In general populations, an LSI score of more than 15% is considered abnormal.[7,18,20,23] None of our 3 populations recorded an abnormal LSI, but the professional group had a greater imbalance (12%) in the DJ than the other 2 groups. The dominant-limb DJ results show a distinctive trend in favor of the professional players, demonstrating the importance of the stretch-shortening cycle in competitive basketball. In both functional tests, basketball players performed better than the control group. This finding confirms the observations of Viitasalo et al[36] that DJ and other stretch-shortening cycle exercises can differentiate between triple jumpers and nonathletes.[8] Training-induced differences in neuromuscular and connective tissue structures, as well as improved neuromuscular functioning, may have contributed to the superiority of the athletes in these tests.

Not only is it interesting to consider general force profiles, but it is also appropriate to investigate muscle strength disorders. With respect to muscle strength

Table 7. Individual Relative Isokinetic and Functional Asymmetries in Professional Basketball Players With a History of Knee Injury

	Participant				
Characteristic	1	2	3	4	5
Knee injury	Chondral defect	Chondral defect	Chondral defect	Lateral meniscus lesion	Anterior cruciate ligament rupture
Time since injury (before study)	2 y	7 y	3 y	4 mo	9 y
Treatment	Arthroscopic debridement and shaving	Arthroscopic debridement and shaving	Conservative treatment	Arthroscopic shaving	Bone-patellar tendon-bone reconstruction
Bilateral difference, %					
Knee extensors, $60^{\circ}\cdot s^{-1}$	32.7	19.8	31.1	−21.9	45.5
Ratio knee flexors/extensors, $60^{\circ}\cdot s^{-1}$	−34.4	5.8	−62.3	35.7	−31.9
Knee flexors, eccentric, $120^{\circ}\cdot s^{-1}$	4.8	23.8	−7.1	23.6	35.4
Drop jump	17.5	24.7	9.9	12.0	27.8
10-s height	11.8	23.1	25.3	12.8	29.4

imbalances, bilateral PT ratios of the professional group were generally higher than those of the junior and control groups, and their Ext PT demonstrated asymmetry above the 10% clinical cutoff at 60°·s^{-1} (11.3%). However, the observed differences among groups did not achieve statistical significance. This result confirms the recent work of other authors,[8,26,30,37] who also failed to observe dominance-related asymmetries in lower limb isokinetic strength for a variety of elite athletes (track and field, soccer, and basketball). Theoharopoulos and Tsitskaris[5] noted a difference in ankle plantar-flexor strength in favor of the preferred takeoff limb in professional basketball players. With the observed difference being greater than the 10% limit, they advocated specific training to maintain a balanced state. According to our findings, even after years of the intense basketball practice necessary to achieve elite status, the preferential use of a lower limb for jumping did not seem to induce a bilateral muscle imbalance detectable by isokinetic evaluation of the knee Ext or Fl.

An original part of our study consisted of analyzing data based on the existence or lack of a previous knee injury, as defined earlier. Of all the isokinetic factors, only Ext Con PT 240°·s^{-1} did not display a bilateral difference above the clinical 10% cutoff for the group with a history of knee injury. However, mixed Fl Ecc/Ext Con and Fl/Ext ratios at 60°·s^{-1} were higher in injured than uninjured knees. Extensor strength at 60°·s^{-1} also showed a deficit in the group with a history of knee injury; the mean performance of the limb with a history of injury did not even achieve the statistical cutoff for healthy nonathlete participants (greater than 2.09 Nm·kg^{-1}).[15] All of these results (low Ext PT and high Fl to Ext ratios) confirm damage to the extensor apparatus in the knees with a history of injury. The discriminating nature of eccentric isokinetic testing on knee Fl muscle groups[16] was confirmed by the lower values at 120°·s^{-1} on these muscles in the group with a history of injury.

We conclude that the group of professional players with a history of knee injury displayed an abnormal isokinetic profile, the consequence of insufficient rehabilitation or unloading of the injured limb. This finding could be related to the theory that due to poor neuromuscular control, ACL-deficient participants unload the involved limb to prevent pain and protect the site of injury.[21] Furthermore, Walden et al[38] demonstrated that the risk of suffering a knee injury, especially an overuse injury, was higher in elite soccer players with a history of ACL injury. According to our study, these strength deficits are not unique to ACL injuries and may persist for many years, despite resumption of competitive play. From a clinician's perspective, leaving asymmetries above 10% untreated in professional athletes would seem unprincipled, but further studies to determine standardized criteria for return to sports are necessary.

All 15 players were competing in national-level and international-level professional matches at the time of testing with no specific complaints related to the knee and previous injuries. Their athletic abilities were confirmed by the fact that none of the standard bilateral functional tests (CMJ, CMJ with arms, 10-m sprint) detected a difference between the 2 groups, and these results were similar to those of soccer[24,25] and volleyball[27] players tested in earlier studies. Unilateral functional tests (DJ and 10-second height), however, exposed bilateral asymmetries in the group with a history of knee injury (Table 6). With regard to muscular imbalances, further prospective studies investigating isokinetic and unilateral functional tests are needed to determine statistical cutoffs in healthy basketball players. Then researchers can determine whether players with a history of injury have different results.

Authors of most recent studies establishing isokinetic or functional profiles in active professional athletes did not consider previous knee injuries as an inclusion or exclusion factor. Some authors[4,28] specified that the participants were free of complaints; others[6,11,24,25,30] included active players without stating their injury history. Two of these groups[6,25] investigating elite soccer players reported knee Fl bilateral imbalances in both concentric and eccentric modes. Both groups presumed this imbalance to be due to multiple factors, including different biomechanical situations[6] and lack of motivation or apprehension to maximal testing.[25] However, in 2 recent isokinetic studies, professional soccer[29] and elite handball players[39] showed no muscle strength asymmetry of the knee Ext and Fl muscles, regardless of dominance. However, the authors[29,39] specified that participants had neither a history of knee or ankle surgery nor any condition that interfered with their motor function. Furthermore, Croisier et al[40] screened 617 professional soccer players and demonstrated that after an injury, 65% returned to play despite serious muscle strength disorders.

Considering this literature and the abnormalities noted in both isokinetic and unilateral functional tests in our volunteers with a history of knee injury and absent from the professional players without such a history, we conclude that future researchers investigating professional athletes must consider an athlete's personal injury history. Previous results obtained without this consideration may be biased in a significant way and, thus, would provide an inaccurate representation of sport-specific strength profiles.

In addition, it would be interesting to find out, by means of prospective studies, whether the existence of muscle strength disorders can be considered a risk factor for further injuries in professional basketball players. Similar findings have been observed in soccer players with knee Fl strength disorders. The correction of strength disorders revealed in preseason isokinetic testing of professional soccer players reduced the increased risk of subsequent hamstrings strain.[41] According to Hägglund et al,[42] elite soccer players with previous hamstrings, groin, or knee injuries were 2 to 3 times more likely to sustain an identical injury in the following season.

CONCLUSIONS

According to our results, professional basketball players displayed relative isokinetic knee profiles and functional performances similar to those of junior basketball players, with no dominant-side effect. A trend toward better stretch-shortening cycle test results in the professional group needs to be confirmed. However, when knee-injury history was taken into consideration in the professional group, bilateral isokinetic and functional asymmetries were demonstrated. Professional athletes frequently have a history of knee injury, which must be considered when studying their strength and functional capabilities. Future investigators of sport-specific strength profiles must exclude athletes with a significant injury history to eliminate bias. Further prospective studies are required to find out if these asymmetries are a risk factor and whether correcting them reduces the subsequent risk of knee injury. Our findings also emphasize the need for further research to establish standardized criteria for return to sport.

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