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ISOKINETIC MUSCLE POWER OF THE KNEE EXTENSOR AND FLEXOR MUSCLES AMONG DIFFERENTLY TRAINED PEOPLE IN RELATION TO GENDER

original paper
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ABSTRACT
Purpose. Isokinetic muscle characteristics are important factors in numerous fields of expertise and scientific study. Information about the differences in isokinetic muscle power among individuals at various levels of training advancement has a significant impact on the development of sports training technology, the athlete selection process, and physical therapy and rehabilitation. The aim was to study the differences in knee muscles isokinetic power between differently trained men and women.
Methods. The sample of participants consisted of 159 individuals (84 men and 75 women), divided into 5 groups: the physically inactive (30), the physically active (32), strength and power athletes (33), endurance athletes (32), team sports athletes (32). The absolute and relative average knee flexor and extensor isokinetic muscle power was measured on an isokinetic dynamometer in concentric mode at speeds of 60 and 180°/s. To determine the differences between groups, the multivariate (MANOVA) and univariate (ANOVA) analysis of variance were used.
Results. There were significant differences in the relative isokinetic muscle power between differently trained men ($F = 1.513$, $p = 0.043$) and in the absolute and relative isokinetic power between differently trained women ($F = 1.504$, $p = 0.047$; $F = 1.927$, $p = 0.003$, respectively).
Conclusions. The obtained results indicate that physical activities which are characteristic of strength and power sports to a great extent contribute to the development of isokinetic muscle power and that isokinetic muscle power is a sensitive discriminant factor to determine the differences between men and women at various levels of training advancement.
Key words: dynamometry, training advancement, absolute power, relative power, men, women

Introduction

Power is derived from the work done over a given period of time. Muscle power is one of the main factors enabling movement and plays an important role both in sport and everyday activities. Isokinetic muscle power or power manifested at constant angular velocity is an important information factor in sports training, injury prevention, physical therapy and rehabilitation, as well as in studies dealing with muscle contractile characteristics [1, 2].

The factors which influence the manifestation of muscle power are numerous and include muscle fibre and muscle architecture, neural factors, hormones, muscle temperature; among the most important ones is certainly the level of training advancement, that is, the type and intensity of participation in physical activity [3]. Research has shown that individuals who regularly take part in physical activity manifest greater power than those who do not, that is, there are differences in terms of muscle power among trained and untrained individuals [4–7]. In addition, it has been proven that there are differences in the manifestation of various types of power among individuals who take part in various types of physical activity, that is, athletes involved in various types of sports activity [4, 6–8].

The most used parameter in isokinetic dynamometry is peak torque [1, 2]; however, some previous studies indicate that the use of other isokinetic parame-

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ters is justified [9]. So far, only a handful of studies have looked into the significance of isokinetic muscle power differences among individuals at various levels of training [10–12]. In accordance with the aforementioned, the aim of this study was to evaluate the differences in the isokinetic muscle power of knee flexor and extensor, as one of the largest and most important muscle groups, among men and women at various levels of training advancement. It was hypothesized that there would be differences in the knee flexor and extensor isokinetic muscle power among men and women at various levels of training advancement. On the basis of these research results, we could obtain important information on how and to which extent various physical or training activities contribute to the development of isokinetic muscle power in men and women, as well as whether isokinetic muscle power represents a discriminant factor in the case of individuals at various levels of training advancement, which might influence the development of sports training technology, the athlete selection process, as well as physical therapy and rehabilitation.

Material and methods

Subjects

The sample of participants consisted of 159 individuals (84 men and 75 women), divided into 5 groups: the physically inactive (15 men and 15 women), the physically active (17 men and 15 women), strength and power athletes (18 men and 15 women), endurance athletes (17 men and 15 women), and team sports athletes (17 men and 15 women) (Table 1).

The group of physically inactive individuals consisted of adults who did not take part in any physical activity. The group of physically active individuals involved adults who took part in various physical activities 2–5 times per week but did not take part in the training process, that is, did not take part in daily, systematically planned physical or training activities. These were students of the Faculty of Sport and Physical Education and the The Academy of Criminalistic and Police Studies. The groups of athletes included adults who regularly took part in sports training, who had competitive experience in their sport of choice of not less than 5 years, and who actively competed in higher league ranks of the sports they participated in.

In accordance with the previously defined criterion, the strength and power athletes included judokas (8), wrestlers (8), karatekas (7), boxers (3), kick-boxers (3), sprinters (4) (swimmers, cyclists, runners). The group of endurance athletes comprised long-distance runners (14), cyclists (11), and swimmers (7). Athletes from the group of team sports were soccer players (10), basketball players (5), volleyball players (6), handball players (4) and water polo players (7).

All of the participants were acquainted with the goals of the research, and the testing included individuals who had voluntarily agreed to participate.

Procedures

The isokinetic evaluation of muscle power was carried out on an isokinetic dynamometer, the Kin-Com AP125 (KinCom, Kinetic Communicator; Chattecx Corp., Chattanooga, USA) [1, 13, 14]. The testing was performed on the extensors (Q) and flexors (H) of the right (R) and left (L) leg in an isokinetic concentric work regime at speeds of 60 and 180°/s [1, 13, 14]. The parameters of isokinetic dynamometry included in the research were absolute and relative (in relation to body mass) average muscle power of the extensors and flexors of the right and left knee at speeds of 60 and 180°/s (QR60, QL60, HR60, HL60, QR180, QL180, HR180, HL180).

Prior to the measuring, the participants were informed of the manner of test execution. They were required to warm up for a period of approximately 10 minutes: 5 minutes on a stationary bicycle (4 minutes at 40% of maximum heart rate, 1 minute at 80% of maximum heart rate) and 5 minutes of leg muscle stretching, so that they could manifest maximum abilities with no risk of injury [14]. The subjects were seated on a chair (80°), strapped at the shoulders, waist, and active leg so that the desired muscles were isolated, and they were instructed to grab the belts with their arms during the task [15]. The length of the lever arm was individually determined (lateral femoral condyle), and the resistance pad was placed proximal to the medial malleolus [16]. From that position, the participants performed the maximum extension in the knee joint, starting with the flexed knee at the angle of 90°, and then reverse flexion to the initial position (full range of motion: 90°) [14]. They were instructed to perform the repetitions with maximum strength and at maximum speed. Each participant performed 5 repetitions with the right and left leg (the starting leg was randomly determined) at both speeds, with the first testing carried out at the lower speed (60°/s) [14, 17]. The rest between the sets was 3 minutes [17, 18]. The final result was the average of the maximum power out of the 5 attempts. During the task completion, the participants received verbal encouragement [19].

All of the testing was performed under the same conditions. The participants were tested in the morning (8:00–12:00 AM), they were rested, with no injuries, and had not participated in any physical activity for at least 24 hours prior to the testing. The invigilators were all experienced. The testing was carried out at the Methodology-Research Laboratory of the Faculty of Sport and Physical Education of University of Belgrade, Serbia.

Statistical analysis

The statistical procedures used in the study included descriptive statistics, where the basic parameters of the central tendency and data dispersion measures (mean, standard deviation) were calculated. To determine the differences in isokinetic power among the groups, the multivariate (MANOVA) and univariate analysis of variance (ANOVA) were applied, along with the Bonferroni post-hoc test. Statistical significance of the results was set for $p < 0.05$ and $p < 0.01$ [20]. All the statistical procedures were performed with the SPSS19 (SPSS Inc., Chicago, USA) software.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki and the rules of the Ethics Committee of the Faculty of Sport and Physical Education of University of Belgrade, Serbia (IRB: 484-2, 2011–2018, project number III47015 – Ministry of Education, Science and Technological Development), and has been approved by the authors' institutional review board or an equivalent committee.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 1 represents the descriptive indicators of average age, body height, and body weight of differently trained males and females. It can be concluded that team sports athletes were the youngest (21 ± 2.4 years on average) and the tallest (177.1 ± 8.3 cm on average), endurance athletes were the oldest (26.4 ± 4.1 years on average) and had the lowest body weight (71.3 ± 5.5 kg on average), athletes training strength and power sports were the shortest (173.9 ± 8.3 cm on average), while physically active individuals had the highest body weight (71.8 ± 7 kg on average).

Table 2 shows the general differences (for all the measured variables) in absolute and relative average knee isokinetic muscle power among men and wom-

Table 1. Descriptive indicators (mean ± *SD*) of age, body height, and body weight of the participants

		n	Age (years)	BH (cm)	BW (kg)
Physically inactive	Men	15	25.8 ± 3.7	180.4 ± 7	83.3 ± 12.9
	Women	15	22.9 ± 2.2	169.9 ± 6.8	59.3 ± 8
Physically active	Men	17	24.8 ± 3.6	181.3 ± 6.4	81.5 ± 7.9
	Women	15	22.1 ± 2.3	168.8 ± 5.2	62.1 ± 6.1
Strength and power athletes	Men	18	23 ± 4.2	180.4 ± 7.7	78.9 ± 9.7
	Women	15	22.8 ± 3.1	167.5 ± 9	63.8 ± 11.6
Endurance athletes	Men	17	24.9 ± 4.5	181.5 ± 5.9	73.4 ± 8.7
	Women	15	28 ± 3.8	168.3 ± 5.2	56 ± 6.4
Team sports athletes	Men	17	20 ± 2.7	186.8 ± 8.3	80.9 ± 11.1
	Women	15	22 ± 1.7	167.5 ± 8.4	60.2 ± 8

SD – standard deviation, BH – body height, BW – body weight

Table 2. General differences in absolute and relative average knee isokinetic muscle power among men and women at various levels of training advancement

Wilks' lambda	Value	F	*p*	Partial eta squared	Observed power
Absolute strength (men)	0.551	1.465	0.057	0.139	0.968
Relative strength (men)	0.541	1.513	0.043	0.142	0.974
Absolute strength (women)	0.502	1.504	0.047	0.158	0.971
Relative strength (women)	0.422	1.927	0.003	0.194	0.995

en at various levels of training advancement. We may conclude that in the case of women, there were differences between groups in terms of both absolute and relative power (F = 1.504, p = 0.047; F = 1.927, p = 0.003, respectively), while in the case of the men, differences were determined only for relative isokinetic muscle power (F = 1.513, p = 0.043). It can also be observed that the noted differences were greater in the case of relative than absolute isokinetic muscle power.

In the case of differences among the groups for the particular variables of absolute and relative average isokinetic muscle power (Table 3), we can note that for most parameters there were significant differences between men and women at various levels of training advancement. These differences were greater among women (F = 5.236, p = 0.004) than among men (F = 3.232, p = 0.036), and greater for the parameters of relative (F = 4.842, p = 0.011) compared with absolute (F = 3.626, p = 0.029) knee isokinetic muscle power. In addition, both among men and among women, greater differences were obtained for the parameters of knee isokinetic muscle power measured at the speed of 180°/s (F = 1.908, p = 0.007) compared with 60°/s (F = 1.676, p = 0.019), for the parameters of the left leg muscle power (F = 2.024, p = 0.025) compared with the right leg (F = 1.591, p = 0.028), as well as for the parameters of

Table 3. Differences between men and women at various levels of training advancement for particular variables of absolute and relative average knee isokinetic muscle power

Variable	Men				Women			
	Absolute (W)		Relative (W/kg)		Absolute (W)		Relative (W/kg)	
	F	p	F	p	F	p	F	p
QR60	2.915	0.026	4.345	0.003	4.375	0.003	5.971	< 0.001
QL60	3.245	0.016	5.030	0.001	5.640	0.001	5.926	< 0.001
HR60	2.346	0.062	2.253	0.071	4.073	0.005	6.373	< 0.001
HL60	1.923	0.115	3.931	0.006	5.336	0.001	6.193	< 0.001
QR180	1.945	0.111	2.403	0.057	3.377	0.014	3.565	0.011
QL180	4.003	0.005	4.655	0.002	5.716	0.000	7.603	< 0.001
HR180	2.376	0.059	3.760	0.007	3.065	0.022	3.281	0.016
HL180	2.749	0.034	3.839	0.007	4.940	0.001	8.346	< 0.001

Q – knee joint extensor muscles, H – knee joint flexor muscles, R – right leg, L – left leg, 60 – 60°/s, 180 – 180°/s

Table 4. Descriptive indicators (mean ± SD) and differences in the absolute average knee isokinetic muscle power (W) among men and women at various levels of training advancement

		Right leg				Left leg			
		Extensors		Flexors		Extensors		Flexors	
		60°/s	180°/s	60°/s	180°/s	60°/s	180°/s	60°/s	180°/s
PI	M	163.6 ± 23*	353.6 ± 59	108.5 ± 22.3	239.3 ± 43.4	153.4 ± 26.4*	325.1 ± 41.5	101.7 ± 16.7	232.9 ± 34.3
	W	91.9 ± 22.5**	189.1 ± 43.5*	55 ± 10.3**	123.3 ± 31.6*	88.1 ± 21.6**	179.6 ± 35.1**	54 ± 11.1**	124.5 ± 30.5**
PA	M	187.1 ± 29.6	388 ± 62.5	121.3 ± 18.7	285.9 ± 41.4	180.3 ± 29.3	381.4 ± 48.5	115 ± 15.1	271.5 ± 36.8
	W	110.2 ± 18.4	224.2 ± 34.1	69.6 ± 9.7	160.4 ± 21.1	107.4 ± 18	217.6 ± 28.5	68.7 ± 7.7	160.7 ± 22.8
SP	M	199.5 ± 44*	396.1 ± 76.7	119.2 ± 19.3	247.8 ± 60.8	187.9 ± 4*	388 ± 82.3	119.4 ± 25.2	281.1 ± 61.2
	W	125.3 ± 32.1**	242.2 ± 67.5*	77.1 ± 25.3**	173.2 ± 71.6*	123.8 ± 29.3*	242.2 ± 62**	80.9 ± 25.5**	181.1 ± 55.2**
EA	M	168.6 ± 39.6	340.8 ± 75.3	103.5 ± 21	247 ± 50.8	158.7 ± 33.8	321.6 ± 70.2	106.4 ± 21.8	243.7 ± 56.1
	W	102.8 ± 18.7	197.1 ± 40.8	67.4 ± 11.7	144.3 ± 36.9	101.2 ± 16.8	191.6 ± 37.9	69.4 ± 9.3	156.4 ± 25.9
TS	M	179.5 ± 30.4	375.6 ± 65.9	110.4 ± 19.5	260.5 ± 52.1	177 ± 33.4	374.3 ± 71.8	115.3 ± 24	259.7 ± 48.8
	W	114.9 ± 21.4	225.5 ± 37.2	69.7 ± 14.2	155.5 ± 26	116.1 ± 23.7	226.4 ± 35.3	74.4 ± 21.5	156.5 ± 32.4

SD – standard deviation, PI – physically inactive, PA – physically active, SP – strength and power athletes, EA – endurance athletes, TS – team sports athletes, M – men, W – women
* significant differences between PI and SP at p < 0.05, ** significant differences between PI and SP at p < 0.01

Table 5. Descriptive indicators (mean ± *SD*) and differences in the relative average knee isokinetic muscle power (W/kg) among men and women at various levels of training advancement

		Right leg				Left leg			
		Extensors		Flexors		Extensors		Flexors	
		60°/s	180°/s	60°/s	180°/s	60°/s	180°/s	60°/s	180°/s
PI	M	2.96 ± 0.48**	6.4 ± 1.15	1.95 ± 0.32	4.29 ± 0.52*	2.76 ± 0.43**	5.93 ± 1.06**	1.83 ± 0.2**	4.23 ± 0.72**
	W	2.3 ± 0.44**ǀWW	4.7 ± 0.79*W	1.38 ± 0.19†**ǁWW	3.09 ± 0.61*	2.22 ± 0.51**ǀWW	4.52 ± 0.71†WW	1.36 ± 0.24**ǁWW	3.12 ± 0.62‡**ǁWW
PA	M	3.44 ± 0.55	7.13 ± 1.1	2.23 ± 0.33	5.24 ± 0.62	3.31 ± 0.5	7.01 ± 0.86	2.11 ± 0.27	5.02 ± 0.62
	W	2.65 ± 0.38	5.39 ± 0.71	1.67 ± 9.7†	3.85 ± 0.34	2.58 ± 0.4	5.24 ± 0.69†	1.65 ± 0.16	3.85 ± 0.38‡
SP	M	3.75 ± 0.55**	7.47 ± 0.85	2.25 ± 0.22	5.17 ± 0.78*	3.55 ± 0.56**	7.31 ± 1.07**	2.24 ± 0.3**	5.29 ± 0.79**
	W	2.91 ± 0.4**	5.63 ± 0.93*	1.78 ± 0.34**	4.01 ± 1.21*	2.88 ± 0.33**	5.64 ± 0.74	1.87 ± 0.33**	4.19 ± 0.7**
EA	M	3.4 ± 0.6	6.88 ± 1.06	2.1 ± 0.33	5 ± 0.78	3.21 ± 0.48	6.49 ± 1.01	2.15 ± 0.33	4.93 ± 0.91
	W	2.71 ± 0.24ǀ	5.21 ± 0.64	1.78 ± 0.2ǁ	3.85 ± 0.92	2.68 ± 0.21ǀ	5.06 ± 0.51	1.85 ± 0.17ǁ	4.16 ± 0.53ǁ
TS	M	3.33 ± 0.52	6.93 ± 0.85	2.06 ± 0.41	4.85 ± 1.01	3.28 ± 0.53	6.89 ± 0.9	2.14 ± 0.41	4.82 ± 0.88
	W	2.84 ± 0.36WW	5.59 ± 0.6W	1.7 ± 0.29WW	3.85 ± 0.47	2.89 ± 0.6WW	5.61 ± 0.47WW	1.85 ± 0.58WW	3.87 ± 0.59WW

SD – standard deviation, PI – physically inactive, PA – physically active, SP – strength and power athletes, EA – endurance athletes, TS – team sports athletes, M – men, W – women
† significant differences between PI and PA at $p < 0.05$, ‡ significant differences between PI and PA at $p < 0.01$,
* significant differences between PI and SP at $p < 0.05$, ** significant differences between PI and SP at $p < 0.01$,
ǀ significant differences between PI and EA at $p < 0.05$, ǁ significant differences between PI and EA at $p < 0.01$,
W significant differences between PI and TS at $p < 0.05$, WW significant differences between PI and TS at $p < 0.01$

knee flexor isokinetic muscle power (F = 1.748, p = 0.001) compared with knee extensor isokinetic muscle power (F = 1.564, p = 0.037).

Tables 4 and 5 present the differences between groups of men and women at various levels of training advancement in terms of absolute and relative average knee flexor and extensor isokinetic muscle power. We might conclude that in the case of absolute power, both among men and among women, differences can be found only between groups of physically inactive individuals and strength and power athletes, with the addition that the differences were greater in women. In the case of relative isokinetic power, differences among men were determined only between the group of physically inactive individuals and strength and power athletes, while differences among women were established between physically inactive individuals and all the other groups. Between groups of physically active individuals and athletes, no differences were obtained in the parameters of absolute or relative isokinetic power for the sample of men or women.

Discussion

Isokinetic muscle power is an important factor of sports training, rehabilitation, and other fields of expertise and scientific research which are related to muscle contractile characteristics. This study evaluated the differences in absolute and relative average knee flexor and extensor isokinetic muscle power among men and women at various levels of training advancement.

The results indicate that, generally speaking, there are statistically significant differences in the knee extensor and flexor isokinetic muscle power among men (F = 1.489, p = 0.050) and women (F = 1.715, p = 0.025) at various levels of training advancement (Table 2). As previously mentioned, the type and intensity of physical activity are factors which to a great extent influence the manifestation of muscle power [3]; thus, it was expected that there would be differences in the power measured under isokinetic conditions between men and women at various levels of training advancement.

In the case of absolute power, differences among men and women were determined only between groups of physically inactive participants and strength and power athletes. Generally speaking, physically inactive individuals had significantly lower absolute knee isokinetic muscle power than strength and power athletes (by 39.8% on average). These differences were greater in the case of women, that is, there were differences among women in all the parameters of isokinetic power, while among men, the differences referred only to the muscle power of the left and right leg extensors at the speed of 60°/s. As for relative knee isokinetic muscle power among men, the differences were also observed only between the groups of physically inactive individuals and strength and power athletes. Physically inactive men generally had lower relative isokinetic power than strength and power athletes (by 37.1%), while in the case of women, there were differences between physically inactive individuals and all other groups of participants. In other words, physically inactive women presented significantly lower relative knee isokinetic muscle power than physically active women (by 33.09%), strength and power female athletes (by 43.1%), endurance female athletes (by 35.09%), and team sports female athletes (by 39.6%).

As previously indicated, both among men and among women, in the parameters of absolute and relative knee isokinetic muscle power, the greatest statistically significant differences were obtained between physically inactive individuals and strength and power athletes (p = 0.013). In sports such as judo, wrestling, and karate, muscle power is the basic prerequisite for competitive success [21, 22], and athletes dedicate much of their time to developing muscle power. Thus, there is a clear difference between knee isokinetic muscle power between strength and power athletes and physically inactive individuals. Among women, for the parameter of relative knee isokinetic muscle power, after strength and power athletes, statistically significantly higher values compared with the group of physically inactive individuals were achieved by team sports athletes (p = 0.005) and then endurance athletes (p = 0.009), while the smallest difference was determined between the groups of physically inactive and physically active women (p = 0.022). These results were also expected if we take into consideration that the team sports female athletes included soccer players, volleyball players, and handball players, that is, female athletes involved in sports where leg muscle power is a very significant factor of success [23–25]. Thus, it is both logical and expected that they manifest significantly greater values of knee isokinetic muscle power than physically inactive women. In addition, even though systematic participation in long-distance cyclical activities (running, cycling) and recreational physical activities of various content does not extensively affect the development of muscle power as much as the previously mentioned training, that is, movement ability, a difference in the knee isokinetic muscle power among individuals involved in this type of physical or training activities and individuals who did not take part in physical activity was expected and confirmed in this research.

Among the groups of physically active individuals and athletes with different training background, no statistically significant differences were established in terms of absolute or relative knee isokinetic muscle power, neither among men nor among women, that is, there were no differences in the knee isokinetic muscle power among physically active individuals, strength and power athletes, endurance athletes, and team sports athletes. These results are in accordance with some previous studies that indicate the lack of any differences in isokinetic muscle power among athletes involved in various types of sport, that is, individuals at various levels of training advancement [10]. The outcomes can be ascribed to the specific conditions of muscle work under which the testing on the isokinetic dynamometer was carried out, which significantly differ from those in other types of physical, that is, sports activities [2, 26]. We can assume that individuals who manifest greater power than others in certain tests or movements do not necessarily have to present greater power in isokinetic tests, that is, under isokinetic conditions [1, 2, 13, 15].

As previously indicated, differences in knee isokinetic muscle power among individuals at various levels of training advancement were greater among women than among men (Table 2). In the case of women, generally speaking, there were differences among the groups in terms of both absolute and relative isokinetic power (F = 1.504, p = 0.047; F = 1.927, p = 0.003, respectively), while in the case of men, the differences referred only to the relative knee isokinetic muscle power (F = 1.513, p = 0.043). The obtained results can be ascribed to the influence of testosterone and muscle mass. Previous studies have shown that there is a connection between the level of testosterone and the manifestation of muscle power [27, 28]. We can assume that men at various levels of training advancement included in this research manifested approximately similar results of isokinetic power precisely because of having a higher level of testosterone and more muscle mass than women. In the case of women, the level of testosterone and muscle mass were significantly lower, and thus did not affect the manifestation of power to the same extent. Therefore, the influence of various physical activities or training content on isokinetic muscle power is greater and more noticeable among women.

The differences obtained in the average knee isokinetic muscle power among men and women at various levels of training advancement were greater when power was normalized in relation to body mass (Tables 2 and 3). These results were also expected considering that body mass plays an important role in movement.

The manifestation of muscle power is influenced by muscle strength, which to a certain extent depends on body mass [4, 29]. Individuals with greater body mass manifest greater muscle strength and thus power, which does not necessarily have to denote better muscle contractile characteristics. In numerous movement activities, especially those associated with sport, relative power and strength are especially significant for movement performance [29]. Previous studies have indicated that in tests of muscle power and strength evaluation, it is necessary to take body mass into account [29–31]. The results obtained in this study have confirmed body mass relativization in muscle power testing.

When it comes to the differences in various parameters of average knee isokinetic muscle power among individuals at various levels of training advancement, both among men and among women greater differences were obtained for the parameters of absolute and relative average knee isokinetic muscle power measured at the speed of 180°/s (F = 1.908, p = 0.007) compared with 60°/s (F = 1.676, p = 0.019), for the parameters of left leg muscle power (F = 2.024, p = 0.025) compared with right leg muscle power (F = 1.591, p = 0.028), as well as for parameters of isokinetic flexor power (F = 1.748, p = 0.001) compared with extensor power (F = 1.564, p = 0.037). Previous studies [11] have shown that the differences in isokinetic muscle power between individuals at higher and lower levels of training advancement are greater at higher speeds of testing, since greater movement speeds, that is quicker contractions, are characteristic of sports activities, which this research confirmed. In addition, it has indicated that the differences between physically inactive individuals and athletes is greater in the case of knee isokinetic muscle power of the non-dominant leg [11], which is a consequence of athletes' devoting greater attention to the development of muscle power of both legs. Thus, a difference between the physically active, athletes, and the physically inactive in the case of left knee isokinetic muscle power is logical and clear, considering that the left leg is non-dominant among most participants (in 83.01% of participants, right leg was dominant, i.e. jumping leg). Finally, the results of some previous studies indicate that the ratio between knee extensors and flexors power is significantly weaker among individuals at lower levels of training advancement [26], in whom knee flexors are significantly weaker than the extensors, which is not the case with trained individuals. Thus, the greater difference in the isokinetic muscle power of knee flexors compared with knee extensors among physically inactive and physically active individuals, or athletes, obtained in this study is clear and was expected.

The results primarily indicate that participating in physical activities characteristic of strength and power sports (judo, wrestling, karate) to a great extent influences the development of knee flexor and extensor isokinetic muscle power both in men and in women. In addition, we can assume that in the case of women, almost every type of physical activity contributes to the development of isokinetic muscle power to a certain extent, that is, that even regular participation in physical activities which do not impact extensively on the development of power, such as long-distance running, can to a certain degree influence the improvement in muscle contractile characteristics. We can also conclude that physically inactive women, with the aim of increasing muscle power, can take part in any type of physical activity, not solely strength and power exercises. In the case of men, the situation is somewhat different, that is, the obtained results indicate that those activities which exert higher levels of power (combat) have a significant influence on the development of isokinetic muscle power, while other types of physical or training activities (long-term cyclical activities, team sports) do not significantly impact on the development of power manifested under isokinetic conditions.

It has been indicated that isokinetic power, that is, power measured on an isokinetic dynamometer, is a sensitive discriminant factor to determine differences between individuals who participate in certain types of physical activity and those who do not, but the role in establishing the differences among individuals who take part in various types of physical activities, that is, athletes practising various sports, is still debatable. It has also been stated that in determining the differences between physically inactive and physically active individuals (athletes), isokinetic muscle power is a more sensitive discriminant factor among women; that relative isokinetic power is a more sensitive discriminant factor than absolute isokinetic muscle power; and that with the aim of determining differences in knee isokinetic muscle power among physically active (athletes) and physically inactive individuals, it is more suitable to conduct measurements of the flexor muscles in the non-dominant leg at greater speeds of movement (180°/s).

The main limitation of this study is the muscle groups included and the testing procedure. Namely, the study involved only knee joint flexor and extensor muscles. Further research should focus on other muscle groups important for success in sport. Also, this study did not take into consideration the athletes' training period (preparation, competition), which could influence the obtained results.

Conclusions

On the basis of the results obtained in this study, we can primarily determine that there are significant differences in absolute and relative average knee flexor and extensor isokinetic muscle power among men and women at various levels of training advancement.

The results support the hypothesis that both among men and among women, taking part in physical or training activities characteristic of strength and power sport to a great extent influences the development of knee flexor and extensor isokinetic muscle power, as well as that among women, unlike men, almost every type of physical activity contributes to a certain extent to the development of isokinetic muscle power. It has also been proven that power measured on an isokinetic dynamometer is a sensitive discriminant factor for determining the differences between physically active (athletes) and physically inactive men and women, especially in the case of women, but that the discriminant role in establishing differences between individuals who take part in various types of physical activity, that is, athletes practising various types of sport, is still questionable.

Furthermore, the obtained results indicate the necessity of normalizing data in relation to body weight, especially for discriminatory purposes, when testing muscle power by means of isokinetic dynamometry. Finally, the outcomes can offer normative values of knee flexor and extensor isokinetic muscle power among men and women at various levels of training advancement.

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Conflict of interest

The authors state no conflict of interest.

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