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The influence of exercises under isokinetic conditions on heart rate in males aged between 40 and 51

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The aim of the study was to estimate changes in heart rate (HR) values in response to the exercise under isokinetic conditions, with defined protocol using three different angular velocities and 2 minute break. The subjects were divided into two groups. The first group contained 18 males aged between 40 and 50, and the second group contained 20 males who were 20–30 years old. The heart rate was monitored before, during and after the strength moment measurement under isokinetic conditions of extensors and flexors of knee joint. The strength moment was measured with an angular velocity of 180 °/s, 120°/s and 60 °/s. The number of repetitions of extension and flexion of the knee joint was 10 for the angular velocity of 180 °/s, 8 for the angular velocity of 120 °/s and 5 for the angular velocity of 60 °/s. The break between each series of repetitions took 2 minutes. The peak torques for extensors and flexors of both lower extremities were measured. The peak torque and heart rate values increased with a decrease in the preset angular velocity and were lower in the second group. The results were within the norm accepted for submaximal heart rate index in both age groups.

Key words: *isokinetic, peak torque, strength moment measurement*

1. Introduction

Human muscles produce alternate isometric tones and auxotonic contractions as well as isotonic contractions [1]. Auxotonic contractions are characterized by initial changes in muscle tension and next, the change in muscle length during the isotonic – dynamic phase. Isokinetic exercise is a kind of dynamic exercise, characterized by relatively constant speed of movement. Under isokinetic conditions, muscle activity may be both concentric and eccentric. It may also involve alternate concentric–eccentric or eccentric–concentric contractions [1], [2]. Under isokinetic conditions, exercises may be performed in open or closed kinematic chain [3].

Muscular activity is connected with excitability, contractility and the production of strength or torque. Measurement under isokinetic conditions is one of the methods allowing us to obtain objective data on peak torque (PT) values and the average strength, expressed in newtonmeters (Nm), produced by the muscle groups studied. Relative torque (RT) is an indirect value, calculated from the value of torque per one kilogram of body mass (Nm/kg bm). It also measures muscle work expressed in joules (J). The measurement determines PT angle, expressed in degrees (°), the preset angular velocity, expressed in degrees per second (°/s), power, expressed in watts (W) and many other parameters, obtained or calculated [2]. The measurements performed under isokinetic conditions allow us to determine the deficit in the values of the biomechanical parameters obtained that can be compared to that obtained for the uninvolved extremity. The results may also be compared with these obtained for the group of antagonist muscles and the accepted norms [2]–[4]. The studies and training per-

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formed under isokinetic conditions are common procedures in sport [5], [6]. They are used to monitor the rehabilitation of injuries and conditions of the motor organ [7]–[12]. Such measurements are also used in neurology [13], [14]. Comparative assessment of different methods of surgical procedures also involves isokinetics [15], [16].

So far there have been few studies evaluating the effect of isokinetic exercises on the changes in haemodynamic parameters, particularly in middle-aged patients. Isokinetic exercises, as compared to static exercises, may result in greater changes in arterial blood pressure and exert higher stress on the circulatory system [17]. A standard isokinetic test for knee flexor and extensor muscles contributes to an increase in an average heart rate (HR), up to 135 beats per minute (bpm). It also increases cardiac output (Q) and systolic blood pressure (SBP) in young males [18]. Other authors suggest that patients with stabilized chronic heart insufficiency require particular caution and experienced physicians as well as full clinical protection [19], [20]. Recently, the age limit for patients qualified for surgical procedures has been increased. Middle-aged individuals increasingly often participate in complex rehabilitation programs of motor organ injuries. Some patients participate in all rehabilitation stages during conservative treatment, or following knee ligament reconstruction procedures or Achilles tendon surgery. It is of note that the two final stages of rehabilitation program aim at restoring the patients' ability to enable them active participation in different forms of physical activity, therefore it is essential to restore muscle strength in these patients [21], [22]. Additionally, there is a growing number of middle-aged patients involved in different forms of physical activities, including endurance, strength-endurance and strength speed activities.

The men aged between 40 and 50 face serious risk of circulatory system diseases, being overweight and diabetes. Therefore, their physiological reactions need to be controlled through the application of different kinds of physical exercise [23]. Our goal was to determine, how the suggested protocol of exercises with a reduced number of repetitions during subsequent sets of exercises would change the HR values as compared to the studied biomechanical traits in middle-aged patients.

Our study also aimed at evaluating the effect of isokinetic exercises on HR in males aged between 40 and 50 who underwent protocol using three different angular velocities, with 2 minute recovery.

2. Materials and methods

2.1. Subjects

The study was carried out at the Centre of Rehabilitation and Medical Education of the College of Physiotherapy in Wrocław.

It is well known that excessive strength and strength-endurance activity can pose a risk to circulatory and respiratory systems of middle-aged and elderly people. As an answer to the question which protocol would be safe for 40–50 years old people being tested under isokinetic conditions, there were made some pilot studies on men aged between 20 and 30. There were applied three different protocols of moment strength measurement of muscles of knee joint under isokinetic conditions. The first protocol contained three sets of the repetitions of the alternate extension and flexion of the knee joint examined. The first set was performed at the angular velocity of 60 °/s, the second set was performed at the angular velocity of 120 °/s and the third set was performed at the angular velocity of 180 °/s. In the first set the subjects performed 5 repetitions (reps), in the second set, the subjects performed 10 reps, and in the third set, they performed 15 reps. Between sets there was a 30 s break. In the second protocol applied, the time of the break between sets was extended to 120 s and the number of repetitions was changed. In the first, the second and the third sets, the subjects performed 5, 8 and 10 reps, respectively. The trial repetition before every set was added. In the third protocol, the sequence of sets was changed. After we made sure that the protocol was safe for the group of 20–30 years old men, we used the protocol in the studies on the group of men aged between 40 and 50 and we showed this in the present study.

Table 1. Characteristics of the studied sample

Subjects	Features	Age (years)	Body height (cm)	Body mass (kg)
Group I (n = 18)	Min	40	158	51
	Max	51	185	104
	X	45.8	175.1	82.7
	SD	4.0	7.0	14.4
Group II (n = 20)	Min	21	170	69
	Max	29	189	95
	X	24	178.8	76.85
	SD	2.1	5.8	5.59

The experiment was approved by the Bioethics Committee and the subjects gave their informed consent for participation in the study. The Group I included 18 male subjects aged between 40 and 50, involved in recreational activities after working hours. The Group II comprised 20 males aged between 20 and 30, involved in the same kind of physical activity. Table 1 presents somatic characteristics of the samples examined. The right leg was the dominant extremity in all the subjects.

2.2. Experimental design and procedures

The subjects obtained the physician's consent for participation in the experiment. Each subject was informed about the goal and study protocol and the subject's history was taken. The subjects were free from any medication altering the heart rate response during the experiment. They had their HR recorded with a heart rate monitor (POLAR T31) sensor mounted at the level of the xiphoid process and the receiver – on their wrist. Resting HR (HR rest) was recorded after 15 minute rest in the supine position. Next, the subjects warmed up for 12 minutes on cycle ergometer with a constant speed of 60 revolutions per minute (rpm). During the first six minutes the load was 50 watts (W), and then it was increased by 5–10 in every 2 minutes without interrupting the warm-up. The registration of HR was continuous, but there were chosen time zones when the HR was noted. The highest HR value, obtained during the entire warm-up period, was recorded (HR warm-up). Following the warm-up, HR values (HR after warm-up), measured prior to the measurement, were recorded while the first examined lower extremity was weighed. Next, PT values were measured for the knee joint extensor and flexor muscles, starting with the right legs. The PT was measured under isokinetic conditions at three angular velocities, using HUMAC NORM TESTING & REHABILITATION system. The program was compatible with Windows XP Professional system [24]. The system was first calibrated. The forces were measured in a seat position. The dynamometer axis was in accordance with the anatomic rotation axis of the knee joint examined. The length of the lever was 40 cm for all the subjects. The height of the chair was adjusted and the cushion supported the subject's lumbar spine. Additionally, the lumbar segment was stabilized by an oblong belt at the level of lower rib angles and a four-point belt buckled at the level of the fifth and sixth pairs of ribs. The belt providing thigh stability was tied through the lateral and the middle buckle of the seat at the level of the thigh. The shank of the uninvolved leg was stabilized using a support mounted on a lower part of the seat. During the measurement, the subject's arms were crossed on his chest, and his head was leaned on the chair; his feet were in dorsiflexion. The range of movements was determined and the limb under examination was weighed [24]. The baseline position was maximal flexion of the knee joint. The subject performed a set of repetitions involving alternate extension and flexion of the knee joint. He started the series of repetitions with the 'start' command and ended it with the "stop" command. The set of repetitions was preceded by one trial repetition. Between the trial repetition and the test there was a 10 second break. The number of repetitions in each set varied for different angular velocities. At the angular velocity of 180 °/s, the subjects performed 10 repetitions (reps), at the angular velocity of 120 °/s – 8 reps and at the angular velocity of 60 °/s – 5 reps of alternate extension and flexion of the knee joint examined. There was a 2 minute break between individual series. The maximal HR values (HR max) obtained from each series were recorded. During a 2 minute break between the series of the exercises performed and the trial repetition, HR values were recorded during the 10th second (HR. 10 s break) and during the 110th second of break (HR, 110 s break). When the left leg was measured, all the steps were repeated likewise in the case of the right leg. The PT measurement was followed by exercise restitution in a supine position and the HR values were additionally recorded during the 5th (HR, 300 s restitution) and 10th (HR, 600 s restitution) minute of restitution taken in supine position after finishing the measurement.

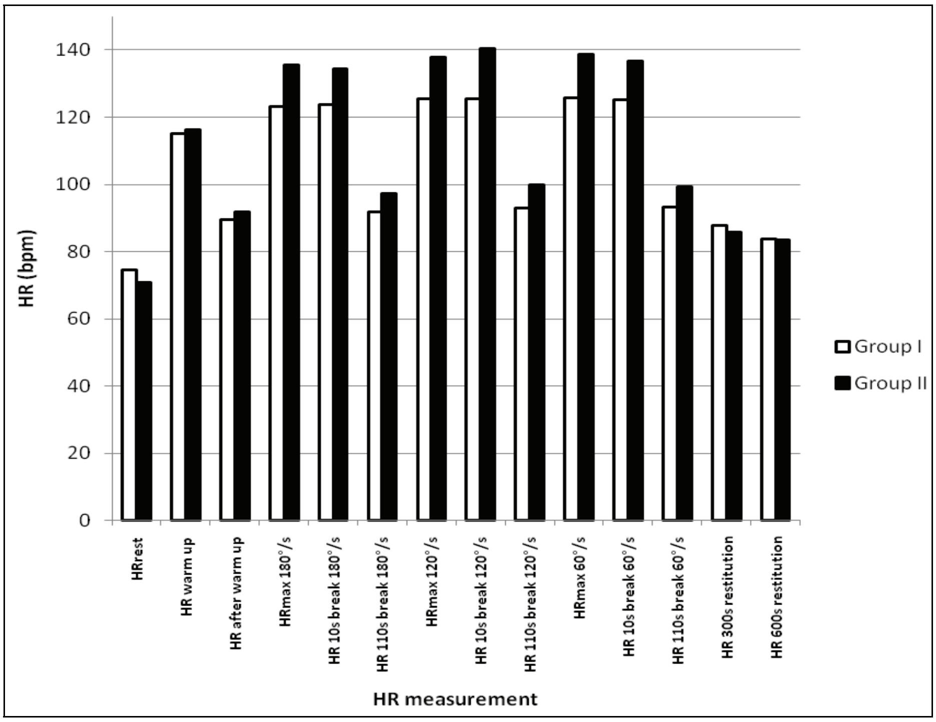
2.3. Statistical analysis

The results were subjected to statistical analysis. For the comparison of the mean values obtained from each group, the Wilcoxon's nonparametric test for dependent samples was applied. The nonparametric Mann–Whitney *U* test for independent samples was applied to compare the between-group differences in the mean values. For the description, the mean values (x) and standard deviations (SD, ±) were used. For statistic analysis the SPSS vol. 17 Multilanguange program was used. The significance of the results obtained was accepted at the level $p < 0.05$ [25].

3. Results

The mean HR rest values x obtained for the Groups I and II equalled 74.7 bpm and 70.0 bpm, respectively. During the warm-up the mean HR values increased to x = 115 bpm and x = 116.4 bpm in the Group I and the Group II, respectively. After the warm-up, these values dropped to x = 89.6 bpm (the Group I) and x = 91.7 bpm (the Group II). The mean maximal HR was x = 123.1 bpm in the Group I and x = 135.5 bpm in the Group II during the PT measurement of the right leg and the left leg at the angular velocity of 180 °/s (HRmax, 180 °/s). After a 10 second break (HR, 10 s break, 180 °/s), the mean HR value reached x = 123.6 bpm in the Group I and x = 134.3 bpm in the Group II. After a 110 second break (HR, 110 s break, 180 °/s), this value dropped to x = 91.7 bpm in the Group I and to x = 97.3 bpm in the Group II. The mean maximal HRs during the PT measurement in the right leg and the left leg at a velocity of 120 °/s (HRmax, 120 °/s) were x = 125.4 bpm and x = 137.8 bpm for the Group I and Group II, respectively. After a 10 second break, the values were x = 125.4 bpm and x = 140.3 bpm for the Group I and the Group II, respectively, for the angular velocity of 120 °/s (HR, 10 s break, 120 °/s). After a 110 second break, the mean HR values for the angular velocity of 120 °/s (HR, 110 s break, 120 °/s) dropped to x = 93.1 bpm and x = 99.9 bpm in the Group I and the Group II, respectively. During the PT measurement of the right leg and the left leg at the angular velocity of 60 °/s (Hrmax, 60 °/s), the mean HR values were x = 125.8 bpm and x = 138.6 bpm, respectively. After a 10 second break, the mean HR values at a velocity of 60 °/s (HR, 10 s break, 60 °/s) were x = 125.1 bpm (the Group I) and x = 136.6 bpm (the Group II). After a 110 second break, the mean HR values at the angular velocity of 60 °/s (HR, 110 s break, 60 °/s) were x = 93.3 bpm (the Group I) and x = 99.3 bpm (the Group II). The mean HR, values obtained after 5 minutes of restitution (HR, 300 s restitution) were x = 87.8 bpm (the Group I) and x = 85.9 bpm (the Group II). The mean HR values obtained after 10 minutes of restitution (HR, 600 s restitution) dropped to x = 83.9 bpm (the Group I) and x = 83.4 bpm (the Group II). The figure presents the characteristics of these changes.

Table 2 shows the mean values (x), standard deviations (SD) and the significance level (p) for the differences in HR values obtained from PT measurement in the knee joint extensor and flexor muscles for both groups during the isokinetic test performed at angular velocities of 180 °/s, 120 °/s and 60 °/s. Thereafter, the changes in HR values were compared for the 10th and 110th second of restitution. Generally, in the first group (males aged between 40 and 50), the mean values of maximal HR increased, on average, from 121.6 to 127.6 bpm. In the second group, these values increased, on average, from 135.1 to 139.3 bpm during the entire isokinetic test. We can thus infer that an increase in the mean HR values, obtained during isokinetic exercises for all angular velocities, was statistically significantly higher ($p < 0.05$) when the load was exerted on the right lower limb, and then on the left one (table 2). At the end of each 2 minute



Mean HR values obtained for both groups during the whole study

Table 2. Comparison of the mean values (x), standard deviations (SD) and significance level (p) for the differences in maximal and restitution HR values obtained in both groups of subjects from the interval isokinetic test for knee joint extensor and flexor muscles with the preset angular velocities of 180 °/s, 120 °/s and 60 °/s

Angular velocity (°/s) and the number of repetitions (rep) within a set		180 °/s 10 reps			120 °/s 8 reps			60 °/s 5 reps		
HR measurement		HRmax	HR, 10 s break	HR, 110 s break	HRmax	HR, 10s break	HR, 110 s break	HRmax	HR, 10 s break	HR, 110 s break
		First test – right leg								
Group I	x	121.6	121.2	89.7	123.3	123.3	90.6	124.3	122.6	92.7
	SD	13.8	15.7	15.0	13.1	13.9	15.9	13.9	15.3	18.6
Group II	x	135.1	132.0	94.0	137.3	138.6	96.6	139.3	135.7	98.7
	SD	1.0	18.0	17.5	14.1	16.1	15.6	14.8	17.3	17.4
	p	$p < 0.05$	ns	ns	$p < 0.05$	$p < 0.05$	ns	$p < 0.05$	$p < 0.05$	ns
		Second test – left leg								
Group I	x	124.7	125.9	93.8	127.6	127.4	95.5	127.3	127.6	93.9
	SD	13.2	14.2	15.8	14.0	14.4	15.7	13.6	15.3	17.6
Group II	x	135.9	136.6	100.6	138.3	142.1	103.3	138.4	137.5	99.8
	SD	13.3	19.4	16.3	16.1	18.6	16.5	17.8	17.6	18.3
	p	$p < 0.05$	ns	ns	$p < 0.05$	$p < 0.05$	ns	$p < 0.05$	ns	ns

Table 3. Peak torque (PT) and relative torque (RT) values and total work (TW) for knee joint extensor and flexor muscles of right legs in both groups of subjects (Q – quadriceps, H – hamstrings)

Angular velocity (°/s) and the number of set repetitions (reps)	Parameter	Group I (n = 18)				Group II (n = 20)					
		Q		H		Q		H		Q	H
		x	SD	x	SD	x	SD	x	SD	p	
180 °/s 10 reps	PT (Nm)	131.8	26.0	71.1	16.3	149.3	22.6	81.7	15.1	$p < 0.05$	$p < 0.05$
	RT (Nm/kg bm)	1.5	0.1	0.8	0.1	1.94	0.2	1.0	0.1	$p < 0.05$	$p < 0.05$
	TW (J)	1398.1		730.1		1578.9		862.0		ns	ns
120 °/s 8 reps	PT (Nm)	156.8	29.1	89.3	19.9	180.1	22.7	108.6	16.4	$p < 0.05$	$p < 0.05$
	RT (Nm/ kg bm)	1.9	0.3	1.0	0.1	2.34	0.2	1.4	0.2	$p < 0.05$	$p < 0.05$
	TW (J)	1443.3		819.3		1642.7		971.2		$p < 0.05$	$p < 0.05$
60 °/s 5 reps	PT (Nm)	183.4	38.9	108.5	23.5	216.7	31.9	127.0	19.5	$p < 0.05$	$p < 0.05$
	RT (Nm/ kg bm)	2.23	0.3	1.3	0.2	2.81	0.3	1.6	0.2	$p < 0.05$	$p < 0.05$
	TW (J)	1092.7		613.9		1204.5		691.5		ns	$p < 0.05$

break between the sets of exercises, the HR values dropped in both groups below 100 bpm after testing the right legs and were lower in the Group I. The values obtained ranged then from 94 to 98.7 bpm and from 89.7 to 92.7 bpm for the Groups I and II, respectively. For the left legs, the HR values obtained during 2 minute break between the sets of exercises varied between 93.8 and 95.6 bpm in the Group I and between 99.8 and 103.3 bpm in the Group II. During the 5th minute of restitution after the isokinetic test, in the Group II the values dropped to 98.7 and 99.8 for the right and left knees, respectively. Lower values were registered in the Group I: $x = 92.7$ and $x = 93.9$ for the right and left knees, respectively, which is presented in table 2. The HR values obtained in the 10th minute of restitution after the interval test were lower than the values obtained after a 12 minute warm-up which preceded the isokinetic test (the figure).

Table 3 presents average values, standard deviations and significance level for the differences in PT values obtained for knee joint extensor and flexor muscles of the right (dominant) leg during the isokinetic measurement with preset values of angular velocity. The PT values obtained for the Group II were statistically significantly higher than these obtained for the Group I (males aged between 40 and 50) at $p < 0.05$. Also the PT values obtained from the three series of exercises with the angular velocity of 180 °/s, after a 2 minute break – with the velocity of 120 °/s and after the next 2 minute break – with the velocity of 60 °/s were significantly higher in this group.

In order to diminish the bias resulting from the effect of different body mass parameters on the PT values in the male population under examination, the relative torque (RT) values were calculated. In the Group II, the RT values obtained both for extensor and flexor muscles of the knee joint during the exercises performed at three preset angular velocities (180 °/s, 120 °/s and 60 °/s) were higher than the corresponding values obtained for the Group I at $p < 0.05$ (table 1). The total work (TW) was significantly greater in the Group II for both muscle groups during the test performed at the angular velocity of 120 °/s and for knee joint extensor at the velocity of 60 °/s (table 3).

The results presented in table 2 indicate that the Group II obtained higher values of relative torque (RT) of the knee joint extensor and flexor muscles in the left leg during the isokinetic test as compared to the values obtained by the Group I for all the preset angular velocities, at the significance level $p < 0.05$. In the Group II, the mean PT values were higher than in the Group I for all the preset velocities (table 4). The total work (TW) was greater for both lower limbs in the Group II during the exercises performed with the angular velocity of 120 °/s.

Table 5 presents the comparison of an increase in the PT values obtained for the muscle groups studied, averaged for both lower limbs, and an increase in HR values related to a decrease in the preset angular velocities in both groups studied. In the Group I, the mean PT values obtained for the knee joint extensor muscles were $x = 131.9 \pm 28.4$ Nm for the angular velocity of 180 °/s, which was the lowest value as compared to $x = 158.1 \pm 32.2$ Nm for the angular velocity of 120 °/s and the value $x = 185.0 \pm 39.5$ Nm obtained at the angular velocity of 60 °/s. The mean PT values of knee joint flexor muscles were $x = 69.2 \pm 17.0$ Nm for the angular velocity of 180 °/s, which was statistically the lowest value related to $x = 87.1 \pm 20.7$ Nm for the angular velocity of 120 °/s and to the value $x = 105.9 \pm 24.8$ Nm obtained at the angular velocity of 60 °/s. The mean HRmax values obtained between the first and the third sets of exercises slightly increased. The differences, however, were statistically insignificant. The mean HR values were: $x = 123.1 \pm 13.4$ bpm for 180 °/s, $x = 125.4 \pm 13.5$ bpm for 120 °/s, and $x = 125.8 \pm 13.4$ for the lowest angular velocity of 60 °/s. The mean PT values for the knee joint extensor muscles were: $x = 149 \pm 21.6$ Nm for 180 °/s, being significantly

Table 4. Mean PT, RT and TW values obtained for knee joint extensor and flexor muscles of the left legs in both groups (Q – quadriceps, H – hamstrings)

Angular velocity (°/s) and the number of set repetitions (rep)	Parameter	Group I (*n* = 18)				Group II (*n* = 20)					
		Q		H		Q		H		Q	H
		x	*SD*	*x*	*SD*	*x*	*SD*	*x*	*SD*	*p*	
180 °/s 10 reps	PT (Nm)	131.8	31.3	67.3	17.9	148.6	21.0	81.8	11.9	ns	$p < 0.05$
	RT (Nm/kg bm)	1.5	0.2	0.8	0.1	1.9	0.2	1.0	0.1	$p < 0.05$	$p < 0.05$
	TW (J)	1406.2		705.4		1583.9		846.7		ns	ns
120 °/s 8 reps	PT (Nm)	159.4	35.7	84.7	21.7	175.0	25.0	104.2	18.1	ns	$p < 0.05$
	RT (Nm/ kg bm)	1.92	0.3	1.02	0.1	2.2	0.2	1.3	0.2	$p < 0.05$	$p < 0.05$
	TW (J)	1434.1		767.1		1640.3		936.8		$p < 0.05$	$p < 0.05$
60 °/s 5 reps	PT (Nm)	186.5	40.2	103.1	26.3	205.7	31.0	123.5	16.7	ns	$p < 0.05$
	RT (Nm/ kg bm)	2.2	0.3	1.2	0.2	2.6	0.3	1.6	0.2	$p < 0.05$	$p < 0.05$
	TW (J)	1060.0		581.8		1154.3		691.5		ns	ns

Table 5. Comparison between group differences in the PT values obtained for the decreasing angular velocity of 180, 120 and 60 °/s and an increase in HR values (Q – quadriceps, H – hamstrings)

			180 °/s		120 °/s			60 °/s		
			x	*SD*	*x*	*SD*	*p*	*x*	*SD*	*p*
Group I	PT (Nm)	Q	131.9	28.4	158.1	32.2	$p < 0.05$	185.0	39.5	$p < 0.05$
		H	69.2	17.0	87.1	20.7	$p < 0.05$	105.9	24.8	$p < 0.05$
	HRmax (bpm)		123.1	13.4	125.4	13.5	ns	125.8	13.4	ns
Group II	PT (Nm)	Q	149	21.6	177.6	23.8	$p < 0.05$	211.2	31.6	$p < 0.05$
		H	81.8	13.5	106.4	17.3	$p < 0.05$	125.3	18.0	$p < 0.05$
	HRmax (bpm)		135.5	13.0	137.8	15.0	ns	138.6	16.7	ns

lower as compared to x = 177.6 ± 23.8 Nm for 120 °/s, and the highest value x = 211.2 ± 31.6 Nm obtained at the angular velocity of 60 °/s. The mean PT values obtained for knee joint flexor muscles were: x = 81.8 ± 13.5 Nm for 180 °/s, which was statistically the lowest value as compared to x = 106.4 ± 17.3 Nm for 120 °/s, and x = 125.3 ± 18.0 Nm for 60°/s. Conversely, the mean HRmax values, obtained between the first and the third sets of exercises, only slightly increased and did not statistically differ. The mean HR values were x = 135.5 ± 13.0 bpm and x = 137.8 ± 15.0 bpm for the angular velocities of 180 °/s and 120 °/s, respectively, and x = 138.6 ± 16.7 bpm for the lowest angular velocity of 60 °/s. The Group II achieved higher PT and HR values, both for the right and left legs, as compared to the Group I, which is presented in detail in tables 2, 3 and 4.

4. Discussion

The studies evaluating the values of biochemical parameters obtained from tests or exercises performed under isokinetic conditions are well known [7]. The isokinetic protocol evaluates muscles affecting knee joints at the angular velocities of 180 °/s and 60 °/s or at three angular velocities of 60 °/s, 120 °/s and 180 °/s. Numerous studies use different isokinetic protocols [2]. Sometimes the number of repetitions during the exercises performed under isokinetic conditions is varied. The exercises are cyclic or there are sets of exercises with time for recovery [2], [3]. During strength-endurance or strength-speed isokinetic exercise performance for selected muscle groups in middle-aged individuals, we should consider physiological effects of the preset stress, particularly circulatory system responses [23]. The effect of such exercises on the circulatory and respiratory systems, particularly HR values, has been frequently reported. Therefore, the changes in ECG record, arterial blood pressure (BP) or oxygen uptake (VO_2) due to the preset endurance exercise are studied under physiological and pathological conditions [26]. There are fewer data on the effect of resistance exercise, particularly under isokinetic conditions, on the changes in physiological responses, particularly these of the circulatory and respiratory systems in humans [17], [27]. We may wonder, to what extent the changes in heart haemodynamic responses to the PT values (Nm) and power values (W) are due to the exercise performed and whether there are any correlations between the biomechanic parameters and physiological responses obtained.

So far, the studies have been focussed on the effect of strength exercises on the changes in muscle protein levels [28]. More importantly, the main goal of these studies was to determine how specific training may influence the changes in inner muscular structure, muscle mass and strength [29], [30].

The study evaluated the changes in HR values in response to the preset physical exercise under isokinetic conditions, with a defined interval protocol in males aged between 40 and 50. The results were then compared to these obtained from the control group of males aged between 20 and 30.

The results indicate that the mean values of HR increase obtained in the isokinetic test were higher in the Group II that in the Group I. At the same time, the HR values obtained in the isokinetic test did not exceed the accepted submaximal values for each age group, and were 124.8 bpm and 137.3 bpm in the Group I and the Group II, respectively.

It is of note that the individual analysis of maximal HR values, obtained from males aged between 40 and 50, proves that only one subject reached the HR value of 150 bpm; however, this value also conformed to the acceptable norm of the submaximal HR values determined for the subject's age group. During a 2 minute recovery between the sets of exercises, and next, during the 5th and 10th minutes of recovery, the HR values obtained were higher than the HR rest values and lower than the HR values obtained during the warm-up. This is indicative of a sufficient recovery, as illustrated by the figure and the values in table 2.

An increase in HR values involved physiological response to isokinetic exercises, which affected the mean RT values obtained by working muscles at the three preset angular velocities. The RT values obtained were within 1.9 and next, 2.3 and 2.8 (Nm/kg bm) in the Group II during the third set of exercises. The RT values obtained in the Group I were lower in all the tests – within 1.5, 1.9 and during the third set – 2.2 (Nm /kg bm). The RT values of the muscle groups obtained from left knees were slightly lower in both groups as compared to the right knees, although the trend was similar to that for the right knees. The PT values obtained at the angular velocity of 60 °/s were within the average values of males from this age group doing different jobs requiring average levels of physical activity [31]. The Group II (young males) achieved from 70 to 80% of maximal PT values, determined for males from this age range whose jobs required average levels of physical activity [31]. The mean increase in HRmax values at x = 124.8 bpm involved physiological response to total work performed during the entire isokinetic test at x = 12052.6 J. The mean HRmax value obtained for the Group II, x = 137.3 bpm, was lower compared to that obtained for the Group I. This involved the response to greater total work at x = 13753.7 J. The total work (TW) obtained for the Group II was by 12% higher than that obtained for the Group I. However, the analysis of physiological effects of exercise performed on one heart beat revealed similar results in both groups, and the result obtained in the Group II was only by 4% higher than that in the Group I (table 6). These lower HR values were due to a smaller number of exercise performed by the Group I as compared to the Group II.

Table 6. The mean TW and HRmax values and W/HR in both groups during the entire isokinetic test

n =38		Total work (J)	HRmax	Work (J)/HRmax
Group I	x	12052.6	124.8	96.6
Group II	x	13753.7	137.3	100.2

The study also revealed a significant increase in PT and RT values, directly proportional to a decrease in the preset angular velocity during consecutive sets of exercises. The result is in conformity with the principle of Hill equation, determining the correlation between strength development and the speed of muscle shortening [32].

A significant increase in HR values was noted during the preset physical exercise in the isokinetic test, as compared to the rest values. Conversely, the maximal HR values during exercise performance at increasingly lower angular velocity did not differ significantly between the three sets (table 5).

The fact that the increase obtained in the HR values was approximately on the same level, despite an increase in overload during the consecutive sets of exercises in each group, remains unclear. The outcome was probably due to a 2 minute recovery between subsequent sets of exercises, allowing for partial recovery. This finding was further confirmed by a decrease in HR values during the 110th second, following each set of exercises (table 3). The next factor that affected the results was a planned decrease in the number of exercises within each set, with gradually lower angular velocities. During the first set of exercises, performed at the angular velocity of 180 °/s, the subjects made ten repetitions. During the second set with the preset angular velocity of 120 °/s that number was reduced to eight repetitions, and next, during the third set, to five repetitions with the preset angular velocity of 60 °/s.

This thesis is confirmed by the results of the smallest total work performed during the third set of exercises at 60 °/s, despite the fact that the highest PT values were obtained during this set (tables 4 and 5).

The results also suggest that the selected haemodynamic changes occurring within the heart and the respiratory system during specific physical exertion may be objectively related to the values of PT, the work performed or the power gained by the muscle groups studied [17], [18], [27]. ELLEUCH et al. conducted a clinical biomechanical evaluation of peripheral isokinetic muscle function and cardiorespiratory capacity in patients suffering from coronary artery disease (CAD) [33]. The subjects were males aged between fifty and sixty. DEMONTY et al. studied the strength and fatigue of the muscles affecting the ankle joint as well as the changes in ECG record and arterial blood pressure, resulting from isokinetic exercises in patients with obliterating arteriopathy as compared to the control group [34]. OKAMOTO et al. in turn estimated the effect of concentric isokinetic exercises on the changes in HR and BP values in healthy males [35]. They found that eccentric exercises compared to concentric exercises stimulate smaller responses of the circulatory system in young individuals. Similar conclusions are drawn by OVEREND et al. who examined two groups of young and elderly males under isokinetic conditions. They observed that in both groups (the mean age of 23.2 and 75.2, respectively) eccentric exercises provoked smaller responses from the parameters of the circulatory system [36]. Our isokinetic study protocol involved concentric exercises. In order to reduce a potential effect of concentric isokinetic exercises involving a substantial increase in haemodynamic responses of the heart in the males examined, the sets of exercises were followed by a 2 minute break. The study protocol resulted in a moderate increase in HR values, favourable for the age group examined (40–50 years). However, it seems necessary to consider a pilot study because the safety of isokinetic exercises for the subjects aged between 40 and 50 requires further confirmation.

It seems reasonable to extend the range of clinical studies including electromyographic tests and arterial blood pressure measurement. Spirometry is also necessary due to the changes in biochemical homeostasis. The goal of such measurement is to determine physiological responses of middle-aged individuals to preset physical exertion, closely defined by measurable biomechanical parameters.

5. Conclusions

1. The males aged between 40 and 51, who underwent the protocol of isokinetic exercises characterized by three different angular velocities and 2 minute recovery between sets of repetitions, increased their mean HR values to the level of the norm accepted for submaximal HR index in this age group.

2. During isokinetic exercises, the PT and HR values increased with a decrease in the preset angular velocity and were higher in the group of younger males, aged between 20 and 30.

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