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THE EFFECT OF SPEED AND ENDURANCE PREDISPOSITIONS OF LOWER EXTREMITY MUSCLES ON CHANGES OF THEIR TORQUES INDUCED BY TRAINING

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The objective of this study was to find out relationships between the predispositions of the studied individuals to speed and endurance exercise and the increments of certain biomechanical characteristics induced by training. The study was carried out in 22 students not engaged at that time in training for performance events. Five times weekly during three weeks, the students performed during each training work about 34 kJ. The measurements included muscle torques of hip joint extensors and knee joint extensors and flexors. In the individuals with predisposition to speed exercises, as compared to those predisposed to endurance exercises, the greatests statistically significant increment of torques was noted after three weeks of training and after three weeks of rest. However, the latter was statistically non significant. The exception was the increased torque of knee extensors, in which the greatest increment was achieved by students with predisposition to endurance exercises.

Key *words:* Muscle torque - Force production - Stretch-shortening cycle

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Introduction

One of the problems in the centre of interest of coaches and sportsmen is the degree in which predispositions, congenital or acquired during training, influence the end result in sport events achieved by sportsmen. A relationship has been demonstrated between the main parameters characterizing the capability of the whole organism (phosphagen power, strength of lower-extremity muscles, blood lactate level) and the fibre composition in the muscles [11]. It is supposed that speed and endurance exercise predispositions of muscles are related also to the type of muscle fibres. The recruitment of various types of motor units depends on the character and intensity of work. During moderate dynamic exercise slow twitch fibres are activated in the first place (type I fibres). Increasing exercise intensity is connected with recruitment of fast twitch motor units (type II) [9]. The studies of Erikson et al. [3] and Gollnick et al. [6] have shown that the ratio of slow twitch to fast twitch fibres is not changed during 4-6 weeks of training in young individuals (aged 11-13 years) and in the adults. As yet, it has not been possible to induce any changes in the per cent of fast twitch fibres in muscles by means of endurance training [5], sprinting or strength training [14]. Similarly, in studies of MacDougall et al. (cf. in 12) no changes were demonstrated in the proportions of these muscle fibres in a group of body-building individuals and in those not engaged in training, studied after 6 months of body-building training. Häkkinen et al. [7] observed after 16 weeks of training followed by 8 weeks of post-training period a greater hypertrophy in the training period and a greater rate of subsequent atrophy after training of fast twitch fibres than slow twitch fibres.

This survey of the published observations showed that in most studies the following problems were investigated and assessed:

- by physiological methods: changes occuring in muscles with various types of muscle fibres developing during training, without consideration of changes in biomechanical characteristics;
- by biomechanical methods: changes in the values of certain biomechanical characteristics of muscles taking place in the period of training, without giving consideration to the type of muscle fibres or to predispositions of the studied individuals to exercise type i.e. speed or endurance exercise.

The objective of the present study was a search for relationships between the predisposition of the studied individuals to speed or endurance exercises and the increments of certain biomechanical characteristics during training of identical volume on a training device, and using the same exercises.

Material and methods

The study was carried out in 22 Academy of Physical Education students not training at that time for performance events. The mean characteristics (±SD) of the group was as follows: age 22.8±1.3 years, body weight 73.5±7.4 kg, body height 178.4±5.6 cm. Before starting the training, the force-time (F(t)) characteristics of right knee joint extensors were determined. The study was conducted on a test stand for measuring muscle torques under static conditions using a system consisting of strain gauge dynamometer with amplifier brigde and recorder [2]. For measurements of the F(t) characteristics the studied individual was told to extend on the command "do it quickly" his lower extremity in the knee joint activating thus the strain gauge sensor connected through an amplifier to the oscillograph which recorded the F(t) characteristics. In all studied individuals the lever arm of the external force was 0.3 m. From the parameters of the F(t) curve the mean rate of force increase to 50% of F_{max} and 75% of F_{max} ($N{*}s^{-1}$) was calculated. Then for classifying the students into groups with speed or endurance predispositions the mean value and the confidence interval were calculated for the μ mean of normal distribution at significance level α=0.01 [13]. The results of all measurements were above the confidence interval in 7 students, and these individuals were included into the group with speed predispositions (PS, n=7). The results obtained in 6 students were in all measurements below the confidence interval, and they were included into the group with endurance predispositions (PE, n=6). The remaining students were included into the group with mixed predispositions (PM, n=9). The mean rates of strength increments significantly differentiated the individuals in these groups (Table 1). The intergroup differences of age, body weight and height were not significant.

T a b l e 1

Mean values (±SD) of the rate of force increase up to 0.5 F_{max} and 0,75 F_{max} for extensors of the right lower extremity (RLE)

		PS[1] (n = 7)	PM[2] (n = 9)	PE[3] (n = 6)
RLE	0.5 F_{max}	4501.1±534.2	3330.4±486.3***	2208.8±343.6###***
RLE	0.75 F_{max}	4609.3±867.2	3017.0±378.2**	2044.3±218.9###**

PM and PE significantly different from PS**; p<0.01, and *** p - 0.001 respectively), PM significantly different from PE, ### p<0.001

[1] PS, [2] PM, [3] PE - explanations in text.

The training device "inclined plane" consisted of a trolley of 29.5 kg weight with changeable back-rest making possible position change of the studied individual from recumbent to sitting, a chute made of steel rails inclined at an angle of $17^{\circ}30'$ in relation to the level. The end-part of the chute was provided with a dynamometric platform connected to an amplifier and recorder (produced by Honeywell).

The experiment was proceded by one week of familiarization with the training device and test procedure. During 5 days each individual performed about 20 various stretch-shortening exercises i.e. trolley-subject system after it was dropped from a certain distance and rapidly pushing the trolley-subject system upwards, on the device.

The number of cycles and the number of exercises in the last cycle were selected individually, for each individual, so that during each training each individual performed work about 34 kJ. On the day of the measurements, the training consisted of 1 x 10 stretch-shortening exercises. Before beginning of the training, after each training week, and after the 1st, 2nd and 3rd weeks after the end of the training period, measurements of muscle torques were done under static conditions.

The measurements were done in a standard way on the stand for muscle strength measurement under static conditions [2]. Muscle torques (MT) were determined of six muscle groups: extensors and flexors of knee joint and hip joint extensors of the right and left lower extremities.

For verification of the validity of the hypothesis on possible relationship between predisposition type and increements of the studied characteristics, the F-test for variance difference was used. Depending on the obtained differences, the appropriate tests were used for the significance of the means i.e. the t-test or the C-test of Cochran-Cox [13]. The results of the comparisons are shown in parenthese, and the significantly greater or smaller compared values were marked with signs > and < respectively. If no significant differences were found the sign = was used.

Results

Table 2 presents changes in the mean values of the measured biomechanical characteristics obtained before training period (0) during this period (1-3) and three weeks after the completion of the training period (4-6) in the studied groups (PM, PS, PE). The greatest increments of the mean values of the sum of muscle torques (MT) obtained for hip joint extensors were noted in the group with predisposition to speed exercises (PS) after the end of the post-training period (15.3%, p<0.01), and after three weeks after training (14.3%, p<0.001). In the group predisposed to endurance exercises (PE) after the end of the training period and in the post-training period, the MT increments were 6.6% and 8.1% respectively but these were statistically not significant. The obtained mean values of the sum of torques for hip joint extensors (HE) were not significantly different between these groups (PS=PM=PE). The only one statistically significant difference was found between the groups PS and PM for the mean values of increments (in %) after three weeks of training period (PS>PM, p<0.05).

For knee joint extensors (KE), the greatest increments were noted in the first week post-training in the group predisposed to endurance exercises (17.5%, p<0.01). In the PS group, the maximal increment was noted in the second post-training week (10.5%, p<0.001). In the PM group statistically non significant MT changes were noted ranging from -4.6% to 3.7%. Statistically significant differences were found between the groups in the mean increments obtained after two weeks of training (PS<PE, p<0.05).

Table 2

Mean (±SD) values of the studied biomechanical characteristics in the group predisposed to speed exercises (PS, n=7), mixed exercises (PM, n=9), and endurance exercises (PE, n=8)

	Rest	Week of training			Post-training (week)		
	0	1	2	3	4	5	6
PS MT [N*m]							
HE[1)]	482.0	506.1	523.9	$551.1^{@}$	524.9	554.6^{*}	$580.4^{\#}$
	±76.5	±99.9	±108.7	±73.5	±114.5	±86.0	±96.8
KF[2)]	154.6	156.0	145.1	158.0	154.9	159.9	155.4
	±27.3	±34.2	±25.3	±30.4	±26.4	±26.5	±30.8
KE[3)]	245.6	244.7	256.9	263.7^{*}	248.7	$271.4^{\#}$	257.4
	±28.0	±44.6	±32.6	±39.2	±51.7	±32.2	±44.7
SELE[4)]	1454.0	1500.7	1560.7	$1628.6^{@}$	1546.7	$1650.9^{\#}$	$1634.9^{\#}$
	±192.1	±260.3	±254.4	±209.6	±307.5	±211.8	±271.5
PM MT [N*m]							
HE	441.8	$477.8^{\#}$	473.2	478.9^{*}	$483.4^{\#}$	507.6^{*}	480.2^{*}
	±97.9	±112.8	±128.5	±128.6	±109.3	±74.3	±89.0
KF	129.4	133.3	125.0	138.2	138.4	142.7	141.6
	±24.2	±25.5	±19.2	±30.2	±27.6	±23.8	±20.0
KE	230.8	239.3	219.8	226.8	236.0	231.4	238.3
	±43.9	±58.7	±40.7	±46.9	±48.3	±40.6	±35.0
SELE	1344.1	$1433.3^{\#}$	1384.9	1410.5	1438.5^{*}	1477.0	1435.9^{*}
	±287.3	±326.0	±301.1	±338.6	±305.2	±213.0	±229.9
PE MT [N*m]							
HE	473.0	507.3	508.3	504.0	485.2	508.0	511.3
	±86.3	±119.1	±122.7	±87.0	±120.6	±99.2	±108.7
KF	133.8	137.2	140.5	124.2	140.8	130.8	133.5
	±20.5	±29.6	±27.5	±19.9	±31.9	±17.6	±26.7
KE	219.5	232.7	251.0^{*}	229.3	$258.1^{\#}$	240.2	251.7^{*}
	±49.2	±63.3	±60.1	±29.4	±54.7	±48.6	±54.0
SELE	1384.0	1479.3	1517.8	1465.3	1485.5	1495.3	1525.2^{*}
	±192.1	±260.3	±254.4	±209.8	±307.5	±211.8	±271.5

[1)] HE, [2)]KF, [3)]KE, [4)]SELE explanations in text
(* – $p<0.05$), # – $p<0.01$, @ – $p<0.001$)

For knee joint flexors (KF), the greatest increments were observed in the PM group in the second (10.2%) and third (9.4%) post-training week, and in PE group in the first post-training week (15.2%). The mean MT sum values for knee joint flexors in groups PS and PE, observed after completion of the training cycle, were significantly different (PS>PE, $p<0.05$). Statistically significant differences were noted also for the mean per cent increments obtained after 3 weeks of training (PS>PE and PM>PE, $p<0.05$).

For the MT sum of extensors of both lower extremities (SELE) the greatest increments were observed in the group predisposed to speed exercises after three weeks of training (12.0%, $p<0.001$) and in the second (13.5%, $p<0.01$) and third (12.4%, $p<0.01$) post-training week. In PE group the greatest increment was after three post-training weeks (10.2%, $p<0.05$), and in group PM in the first post-training week (7.0%, $p<0.05$). The mean per cent values of increments in the first post-training week were significantly different between PS and PM groups (PS>PM, $p<0.01$).

After calculation of the obtained MT values per one kg of body weight (Table 3), it was found that the mean of the MT sums per kg in the hip joint extensors before the training were not significantly different (PS=PM=PE). Statistically significant differences were noted between groups PS and PM after training completion (PS>PM, $p<0.05$) and in the second (PS>PM, $p<0.05$), and third post-training weeks (PS>PM, $p<0.05$).

Significant differences of the sum of relative MT of knee flexors were found (Fig. 1) before beginning of the training period (PS>PM, PS>PE, $p<0.05$). In the 1st, 2nd, 3rd and 5th weeks of the study significant differences were noted between groups PS and PE (PS>PM, $p<0.05$), and in the 3rd and 5th weeks between groups PS and PE (PS>PE, $p<0.05$). After three weeks of training the obtained per cent increments of the relative MT differed significantly (PS>PE and PS>PM, $p<0.05$).

Table 3

Mean values (±SD) of relative muscle torques in the groups predisposed to speed exercises (PS, n=7), mixed type of predisposition (PM, n=9), and endurance exercises (PE, n=6)

	Rest	Week of training			Post-training (week)		
	0	1	2	3	4	5	6
PS MT [$N*m*kg^{-1}$]							
HE[1]	6,73	7,05	7,28	7,72@	7,28	7,77*	7,81#
	±0,52	±0,83	±0,89	±0,62	±0,93	±0,94	±0,77
KF[2]	2,16	2,17	2,04	2,20	2,17	2,24	2,17
	±0,25	±0,27	±0,31	±0,27	±0,32	±0,34	±0,32
KE[3]	3,45	3,42	3,61	3,69*	3,47	3,81#	3,60
	±0,33	±0,39	±0,37	±0,29	±0,55	±0,32	±0,43
SELE[4]	20,34	20,91	21,78	22,80@	21,50	23,14#	22,81#
	±192,1	±260,3	±254,4	±209,6	±307,5	±211,8	±271,5
PM MT [$N*m*kg^{-1}$]							
HE	5,95	6,43#	6,36	6,43#	6,50#	6,86*	6,49*
	±0,85	±0,97	±1,16	±1,14	±0,88	±0,55	±0,76
KF	1,76	1,81	1,70	1,86	1,87	1,93	1,92
	±0,29	±0,33	±0,22	±0,27	±0,26	±0,20	±0,22
KE	3,12	3,23	2,98	3,06	3,18	3,12	3,23
	±0,44	±0,66	±0,44	±0,43	±0,42	±0,36	±0,32
SELE	18,13	19,31#	18,66	18,97	19,36*	19,96	19,41*
	±2,27	±2,95	±2,50	±2,91	±2,38	±1,37	±1,75
PE MT [$N*m*kg^{-1}$]							
HE	6,42	6,91	6,86	6,85	6,56	6,93	6,94
	±1,03	±1,54	±1,27	±0,97	±1,31	±1,21	±1,26
KF	1,82	1,86	1,90	1,69	1,91	1,78	1,81
	±0,21	±0,35	±0,22	±0,18	±0,34	±0,21	±0,30
KE	2,96	3,14	3,37#	3,12	3,50#	3,26	3,41*
	±0,49	±0,83	±0,53	±0,30	±0,57	±0,58	±0,59
SELE	18,76	20,07	20,45	19,92	20,09	20,37	20,68
	±2,93	±4,27	±3,51	±2,38	±3,53	±3,50	±3,65

[1] HE, [2] KF, [3] KE, [4] SELE explanations in text
(* - $p<0.05$), # - $p<0.01$, @ - $p<0.001$)

The mean values of the relative MT for knee extensors (Fig. 2) measured before the training did not differ significantly (PS=PM=PE). In the second week of training the mean values in groups PS and PM differed significantly (PS>PM, p<0.01). After three weeks of training statistically significant differences were

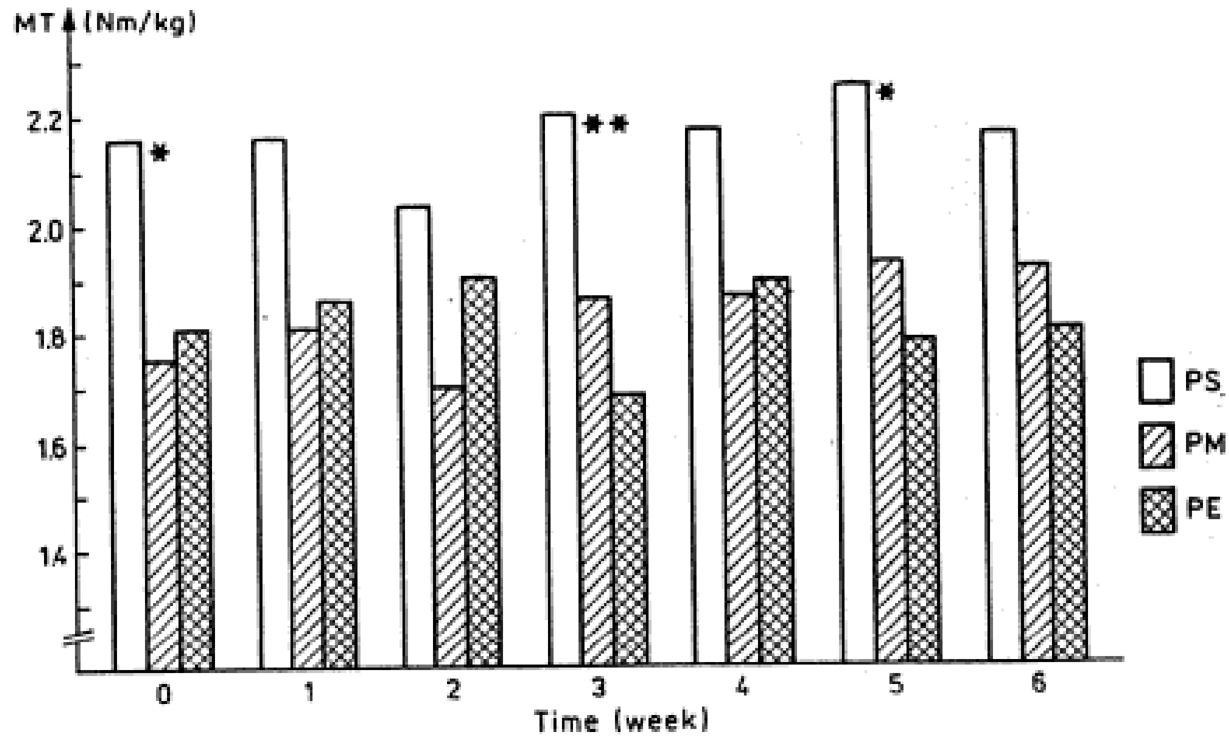

Fig. 1. Changes of the mean values of the sum of relative muscle torques (MT) of left and right knee joint flexors, and significance of the differences of mean values between the studied groups with predisposition to speed exercises (PS) and to endurance exercises (PE)
* - p<0.05, ** -p<0.01

observed between groups PS and PM, and between PS and PE (PS>PM, PS>PE, p<0.01). In the second post-training week the mean values in groups PS and PM differed significantly. On the other hand, in the mean per cent values of increments significant differences were

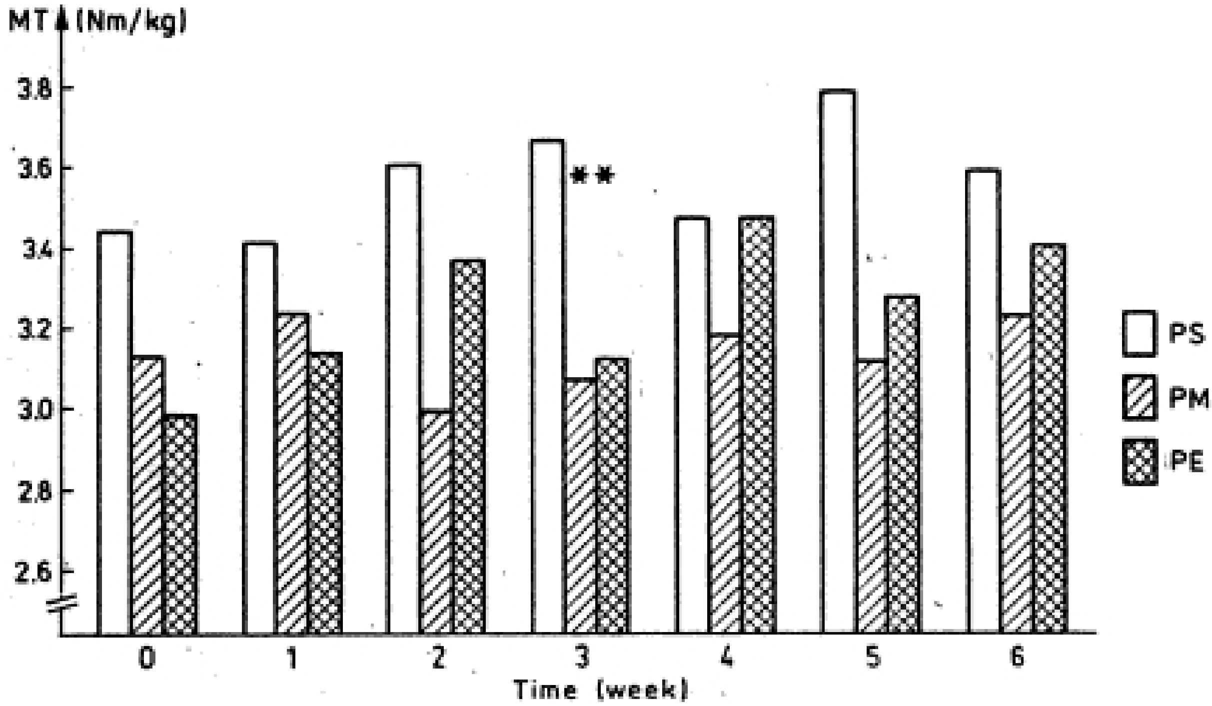

Fig. 2. Changes of the mean values of the sum of relative muscle torques (MT) of right and left knee joint extensors, and the significance of differences between the mean values in the studied groups with predisposition to speed exercises (PS) and endurance exercises (PE). PS significantly different from PE; ** $p<0.01$

noted between groups PM and PE in the second week of training (PM<PE, $p<0.05$), and between groups PS and PE, and PM and PE in the first post-training week (PS<PE, PM<PE, $p<0.05$).

The sums of relative MT of extensors of both lower extremities before the beginning of the training were not significantly different between groups PS and PE (PS=PE), and PE and PM (PM=PE). A difference was noted between PS and PM groups (PS>PM, $p<0.05$). Similarly, statistically significant differences were found in successive control measurements between PS and PM groups (PS>PM, $p<0.05$). In the third week, significant differences were noted between PS and PE groups (PS>PE, $p<0.01$), as well as significant differences between per cent increments between groups PS and PM (PS>PM, $p<0.05$).

Discussion

The development of the knowledge on the structure of muscles and on the importance of the per cent composition of muscle fibre type for the end-result in sports events [11] caused that simpler and quicker methods have been sought for determination of muscle fibre type without application of biopsy [1,10]. The studies of Viitasalo and Komi [18] suggested a relationship between isometric force and the rate of force increase, on the one hand, and the structure of muscle fibres, on the other hand. If the fact is considered that the skeletal muscles of sportsmen, participating in various sports, have different structure of muscle fibres [5,11], a relationship should be supposed to exist between the sports discipline practised by sportsmen and the parameters of the F(t) curve obtained during isometric contraction. This has been confirmed by the results of the studies of Häkkinen and Myllyla [8] demonstrating shorter times of force increase and greater values of the coefficients of rate of force increase in group of "power" sportsmen (judo, ski jumps) and "strength" sportsmen (weightlifters), with longer times of force increase and lower rate of force increase in the group of "endurance" sportsmen (long-distance runners). The rates of force increase were, approximately, 4800 ($N*m^{-1}$) for "power" sportsmen, 4200 ($N*m^{-1}$) for "strength" sportsmen, and 3000 ($N*m^{-1}$) for "endurance" sportsmen. The differences between the "power" group and "endurance" group ($p<0.001$), and between the "strength" group and the "endurance" group was statistically significant. The rate of force increase during training seemed similar in the individuals qualified into the group with predisposition to speed exercises and the group predisposed to endurance exercises. Probably, in the stretch-shortening cycle exercise of about 100% intensity, all types of muscle fibres are participating, and the fast twitch fibres undergo training-induced hypertrophy more rapidly and to a greater degree than the slow twitch fibres [7]. Thus, strength depends, among others, on the physiological cross-section [4]. In view of this one may expect that the individuals with predisposition to speed exercises have greater increments of the studied biomechanicl characteristics than those in the group predisposed to endurance exercises. In the present study the greatest increases of muscle torques were noted in the group predisposed to speed exercises, and the lowest ones in the group predisposed to endurance exercises. This was particularly evident calculating the results per kg of body weight. The only exception were the results of torque determinations for knee joint extensors, in which the greatest increases were observed in the first post-training week in the "endurance group", as compared to groups predisposed to speed exercises or with mixed predispositions. In the case of relative torques of knee extensors the mean per cent increments were also significantly higher in the PE group than in PS and PM groups. However, the mean values of the developed relative torques were after three weeks significantly higher in the group predisposed to speed exercises than in the group predisposed to endurance exercises.

The obtained results suggest that predispositions of muscles to exercise were without any important influence on the post-training changes of muscle torques under static conditions.

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Wpływ predyspozycji szybkościowych i wytrzymałościowych mięśni kończyn dolnych na zmiany ich momentów sił pod wpływem treningu

Streszczenie

Celem pracy było poszukiwanie związku między predyspozycjami badanych do wysiłków szybkościowych i wytrzymałościowych a przyrostami wybranych cech biomechanicznych pod wpływem treningu. W badaniach uczestniczyło 22 studentów AWF aktualnie nie trenujących wyczynowo. Badani pięć razy w tygodniu, przez trzy tygodnie wykonywali na każdym treningu pracę ≈ 34 kJ. Wykonywano pomiary: momentów sił mięśniowych w statyce mięśni prostowników stawu biodrowego, zginaczy i prostowników stawu kolanowego. U badanych o predyspozycjach szybkościowych stwierdzono w porównaniu z grupą badanych o predyspozycjach wytrzymałościowych największe przyrosty momentów sił po 3 tygodniach treningu (istotne statystycznie) i po 3 tygodniach odpoczynku (nieistotne statystycznie). Wyjątek stanowiły przyrosty momentów sił mięśni prostowników kolana, gdzie największe przyrosty osiągnęli badani o predyspozycjach wytrzymałościowych.

Влияние скоростных и выносливых предрасположенностей мышц нижних конечностей на изменения их силовых моментов под воздействием тренировки

Резюме

Целью настоящей работы были поиски связи между предрасположенностями исследуемых к скоростным и выносливым усилиям и приростом

выбранных, биомеханических качеств под влиянием тренировки. В исследованиях приняли участие 22-а студента АФВ, не занимающиеся в данный момент рекордистским спортом.

Студенты подвергались исследованию пять раз в неделю на протяжении трёх недель и выполняли на каждой тренировке работу около 34 kJ. Были проведены измерения: силовых моментов мышц в статике, мышц разгибателей тазобедренного сустава, сгибателей и разгибателей конечного сустава. У исследованных со скоростными предрасположенностями было отмечено по сравнению с группой с выносливыми предрасположенностями самые болшие приросты силовых моментов после трёх недель тренировки (существенные статистически) и после трёх недель отдыха (несущественные статистически). Исключение составляли приросты силовых моментов мышц разгибателей колена, где самых больших приростов достигли исследуемые с выносливыми предрасположенностями.