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Original paper

Contralateral effects after power training of isolated muscles in women

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The purpose of that study was to determine the effect of training of one side of the body on changing the value of the muscle torques on trained and untrained sides. Twenty female students from the Warsaw University of Physical Education were subject to a four-week knee joint power training regimen on the specially designed stand. The same load but different rest time between lapses (120 vs. 30 seconds) were applied to both groups. The load was applied in a form of bending moment equal to 30% of MVC. Bilateral knee force was measured on the Biodex System 3 Pro under isometric conditions. Extension of the rest time between lapses resulted in a higher increase of the strength build-up. Power training causes a similar increase of force generating capacity in both groups for untrained leg. Therefore we have to conclude that there is no influence on homogeneous force improvement for untrained leg after power training.

Key words: *muscle strength, power training, women, lower limb, one-sided training, repeated training*

1. Introduction

Under conditions of isometric contraction there are no significant differences in muscle strength between lower left and right limbs [1]. Lower limbs in not-training patients have a narrow scope of work and their activities are limited mainly to locomotion. BURNIE and BRODIE [2] demonstrated the lack of dominance of the left or right limb in not-training patients during measurement of straightening and bending the knee under isokinetics conditions, while NEUMANN et al. [3] showed the same but in the static hip joint. However, it is incontrovertible that there are people who has superiority (dominance) of one side of the body known as lateral predominance. This predominant side, the upper or lower limb, is called the dominant or leading. For example, dominant lower limb was observed in the group of football players [4]–[6]. However, other authors [7], [8] who also examined the players showed no significant differences in muscle strength in both lower limbs.

The results of many researchers indicate that after strength training, when only one limb was subject to training, there was observed an increase in strength of the opposite side [9]–[13]. However, none of the authors observed muscle hypertrophy accompanying that substantial gain in power [14], [15]. Taking into account that fact it was concluded that gains in strength in the untrained side largely depended on the adaptive changes that occurred in the nervous system [16], [17]. Contralateral effects of power training were tested in groups of men [5]. By contrast, the studies on women were limited to one-sided training conducted under isometric conditions [18]–[20].

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The aim of this study was to determine the effects of power training limited to right knee extensors muscles in women.

2. Material and methods

The study involved female students of the University of Physical Education in Warsaw, who were divided into two groups, K1 and K2. In the table, there are presented average values of age, weight and body height. Participants were familiarized with the purpose of the experiment and gave their written consent to participate in the study. The experiment has been approved by the Ethics Senate Committee at the University of Physical Education in Warsaw. The measurements of height were made using anthropometer, while body weight was recorded on the dynamometer platform, as a part accompanying the measurement of jump height and power.

The values of body weight and height measured in both groups at the beginning of the experiment did not differ significantly.

Table. Mean ± SD values of body weight and height in groups K1 and K2, n – the size of the group

Group	Age (years)	Body weight (kg)	Body height (cm)
K1 (n – 11)	21 ± 1.4	62 ± 7	170 ± 5
K2 (n – 9)	21 ± 1.2	65 ± 8	169 ± 7

The experiment lasted 39 days and was preceded by preliminary studies. During four weeks the trained women participated in the test on the stand described in section 2.2. Training took place five times a week and consisted of 4 series of 10 straights in the knee joint each. In group K1, there was applied a 120-sec interval between series, while in K2 group that interval lasted 30 seconds. Every Monday before training there were made measurements of muscle force moments in static conditions. After four weeks of training over the next two weeks the control tests were performed, including moments of forces.

For the results obtained the significance of differences between mean values was assessed using analysis of variance (ANOVA) and Student's t-test for dependent samples. For all the tests the test significance at the level $p < 0.05$ was used. The statistical analysis of the results was carried out using STATISTICA v. 7.1 (2008).

2.1. The method of measuring training effects

The measurements of muscle force moments of the knee were made on a special stand shown in figure 1. The stand was made up of the seat, strain gauge sensor and amplifier with display. The chair provided rigidity and was adapted to the typical height of the person examined. Each of the women under examination was stabilized in a seated position. An additional stabilization function played the backrest. For each joint the measurement was conducted twice with an interval of two minutes.

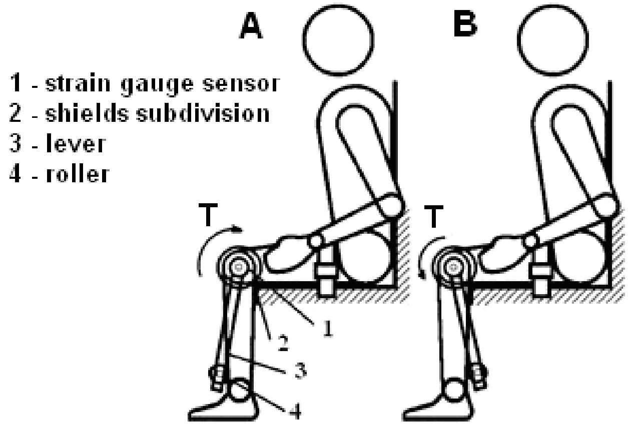

Fig. 1. Position schemes during the measurements of muscle torques (T) under static conditions: A – extension of the knee, B – flexion of the knee joint [5]

2.2. Characteristics of training load to be applied

Training was carried out on a stand presented in figure 2. The device enabled us to measure the performance of the moment of force $M(t)$ and angular path $\Theta(t)$ by means of measuring sensors.

The applied moment acting on the lever forced us to carry out measurements only for the extension of the knee. Therefore, the characteristics of the angular position ($\Theta(t)$) and the moment of force loading the knee joint ($M(t)$) were determined for the angle Θ ranging from 90° to 180°. It was assumed that at $\Theta = 90°$ the shank with the measuring lever was positioned perpendicular to the ground. During the test of dynamic characteristics of force, the task was to carry out the fastest possible straightening in the

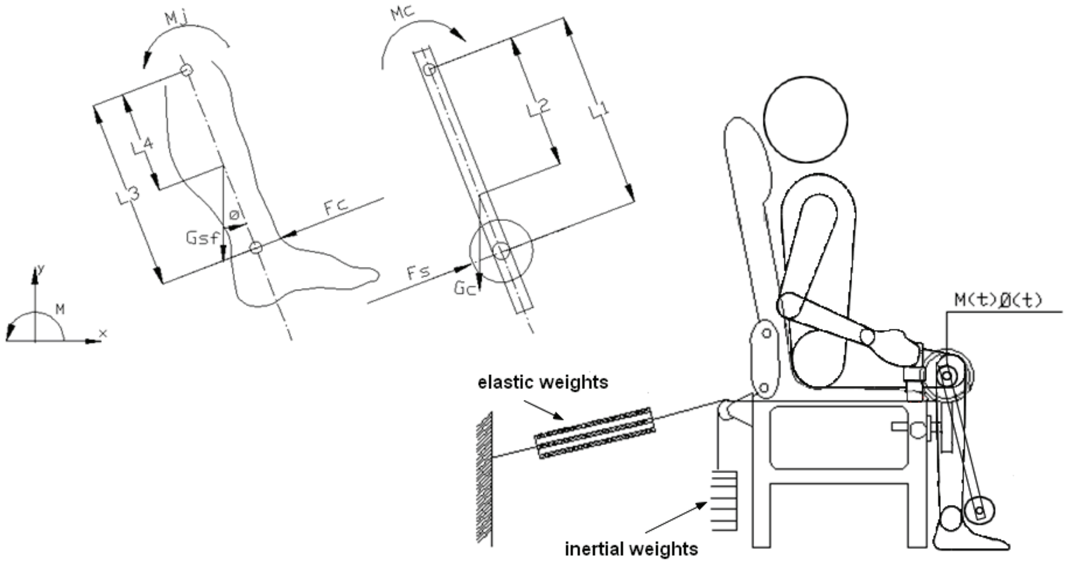

Fig. 2. The stand for training and measuring the power in the function of the external load and the diagram of forces acting on the shank and a lever while straightening the knee. M_i – straightening muscle moment of force at the knee joint, M_c – moment of the forces from the sinker, F_c – the reaction force from the lever, F_s – the power of the arm acting on the lever roller, G_{sf} – the force of gravity shank + foot, G_C – the force of gravity of the lever, L_1, L_2, L_3, L_4 – various sizes of shank and lever, Θ – the angle of the lever swing [5]

right knee. The moment of loading the joint was in the form of elastic bands. The value of mechanical resistance based on the result obtained from the test carried out under static conditions at 90° (MVC). There were adopted moments loading the joint of 30% MVC.

3. Test results

Figure 3 shows the absolute values of muscle torques for the group of muscles straightening left leg and right leg at the knee joint in group K1. Statistically significant differences between left limb and right limb ($t = 2.35$, $p < 0.05$) were observed as early as on 21st day of experiment, and they remained up to 35th day (28 days, $t = 2.41$, $p < 0.05$; the 31st day, $t = 2.92$, $p < 0.01$; the 35th day, $t = 2.82$, $p < 0.01$).

The values of knee flexor muscle torques for right and left lower limbs in group K1 are presented in figure 4. In the initial experiment, the measured values of the flexor to extensor ratio reached 1.66 for the right knee and 1.8 for the left knee. A clear disruption concerned only the right knee. On the 31st day of the experiment, as a result of a significant increase in torque value of knee extensor, the ratio increased to 1.83 (10%) and then decreased to 1.8 (8.3%) and 1.78 (7%) on the 35th and the 39th day of the experiment, respectively.

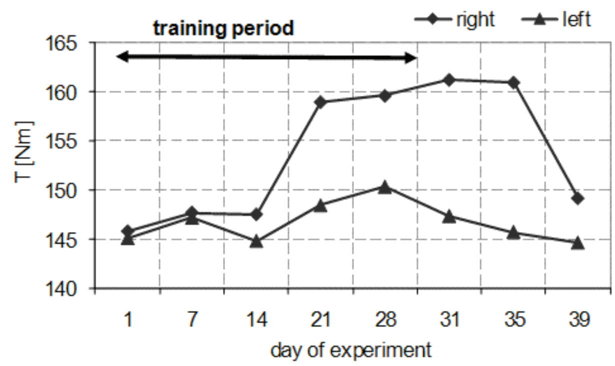

Fig. 3. Absolute values of the muscle torques for the knee extensors of the right leg and left leg in group K1

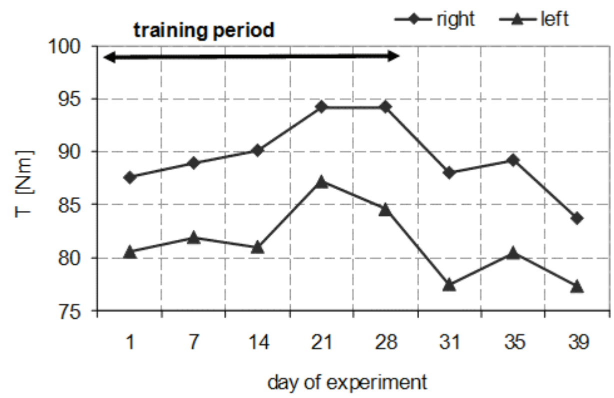

Fig. 4. Absolute value of the moments of muscle torques for the knee flexors of the right leg and left leg in group K1

Absolute values of the moments of muscle forces (T) for the knee extensors of the right and left limbs are shown in figure 5. The biggest difference in the values of muscle torque between left limb and right limb occurred on the 39th day of the experiment (4.7%). There were found no significant differences in the values of muscle torque between left and right knee joints in any of the measurements in group K2.

Absolute values of the torque for knee flexor for right leg and left leg in group K2 were presented in figure 6. At the beginning of the experiment the proportion of extensors to flexors of the right knee and left knee achieved the values of 1.7 and 1.9, respectively. The biggest difference in the proportions took place on the 21st day, increasing to 8% for the right limb and to 6% for the left one. Statistically significant differences in muscle torques between right and left limbs occurred on the 31st day ($t = 2.31$, $p < 0.05$) and the 35th day of the experiment ($t = 3.62$, $p < 0.01$).

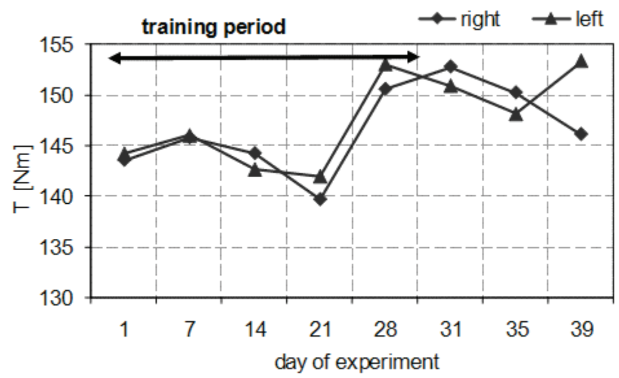

Fig. 5. Absolute values of the moments of muscle torques for the knee extensors for the right leg and left leg in group K2

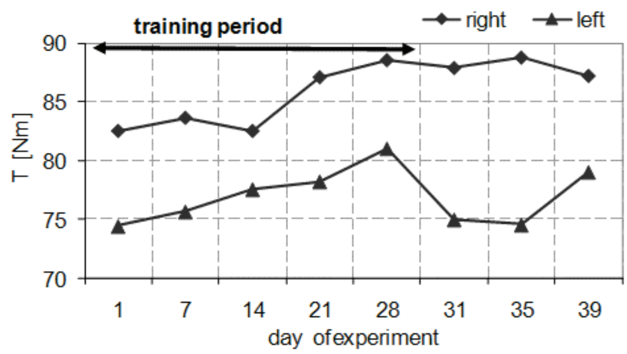

Fig. 6. Absolute values of the moments of muscle torques for the knee flexors for the right leg and left leg in group K2

The percentage change in the values of muscle torques for the right (trained leg) and the left knee extensors for both groups is shown in figure 7. The largest increase in the muscle torque for the right leg occurred in the first week of the test. Group K1 achieved an increase by 4.1% higher than group K2. In group K2, during training, there was observed a decrease in muscle torque for the joint, the largest, by 2.7%, in the fourth week for the right limb, while for the left – by 1.5%.

The largest increases in group K1, in the case of the right limb, occurred in the fourth week of training and remained until the second week of control measurements and on the 31st day of experiment and amounted to 10.6%. However, in the case of the left limb, the largest increase occurred in the first week of tests and amounted to 3.6%. On completion of training in group K2 there was observed an increase in the value, the largest for the right leg, by 6.4% on the 31st day of the experiment, and for the left one, by 6% on the 28th day of the experiment.

Figure 8 shows the percentage increase in the value of muscle torque for the right and left knee flexors in both groups. The greatest increase in the case of the right limb in group K1 occurred in the fourth week of training, while in K2 group it occurred in the second week of tests. Group K1 achieved an increase by 0.05% higher than that in group K2. Moreover, in group K1 at the end of the first week of testing there was a decrease in the values of muscle torque and it

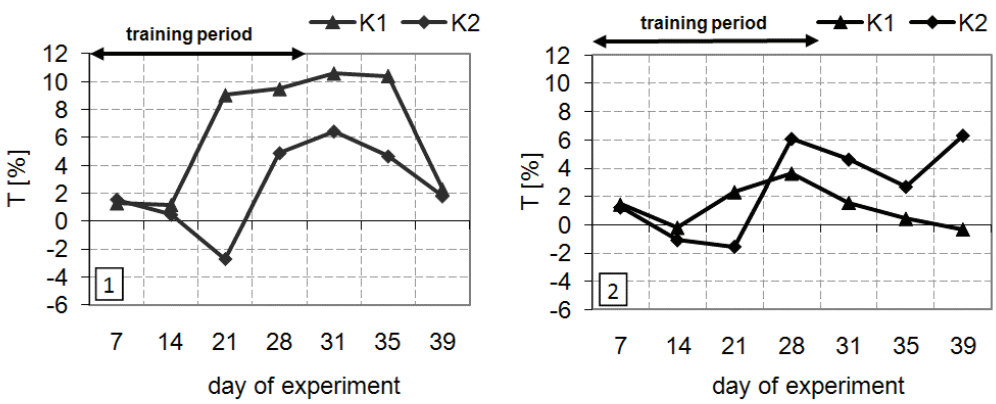

Fig. 7. Percentage change in value for the muscle torques of right (1) and left (2) knee extensors in groups K1 and K2

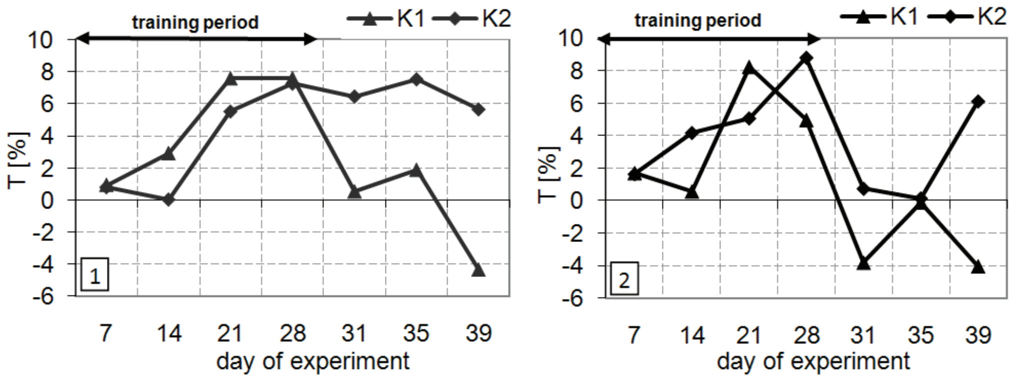

Fig. 8. Changes in the values of the muscle torques for the right (1) and left (2) knee joint flexors in groups K1 and K2

remained until the end of the experiment. However, in group K2 muscle torque values for flexors remained on similar levels throughout the whole experiment. The biggest growth in muscle torque of the flexor in group K1 occurred in the fourth week of training, for the right leg by 7.6%, whereas for the left by 8.2%. In addition, for the left limb at the end of the first week of testing there was a decrease by 3.8%. The largest increases in muscle torque for the flexor of the right limb in group K2 occurred in the second week of control tests (by 7.5%), whereas for the left limb – in the first week of testing (by 8.8%).

4. Discussion

The present studies aimed at assessing the training with the same load, but differing from each other by the leisure break between series and by their influence on the selected lower limb biomechanical parameters in young women.

As we all know, power is an essential element of training, because it allows the player to achieve high sports results [21]. The training load used in that study was individualized, so each of the surveyed women achieved the maximum power in each series of exercises. In addition, a leisure break was arranged by dividing the group into group K1, which had a 120-second break, and K2 with a 30-second break.

Based on previously published works it can be inferred that the minimum training time, which allows us to identify the effects of the loads applied should last from 4 to 6 weeks [22], [23]. In the literature, there can also be found the papers, which describe the research lasting from 8 to 24 weeks [24]–[27]. Analyzing the above works in that experiment, there was used a 4-week training during which the organism was subjected to the effort for 5 days a week.

In order to assess the body reactions to physical effort, in that study muscle torques were measured under static conditions. In the measurements of muscle torque, group K1 achieved in extensor muscle of the knee an increase by 4.1% bigger in comparison to group K2. In group K1, statistically significant increase in muscle torque occurred on the 21st day of the experiment (9.0%), i.e. in the last week of training. On the 31st day of the experiment, there were observed maximum values of muscle torque in group K1. In the case of group K2, the largest increase of muscle force moments occurred on the 31st day of experiment, i.e. in the first week of testing (6.4%), but it was not statistically significant. The effect of training was observed at the same time in both groups; however, it had a different value. This effect was caused by the differences in rest time. Since the four-week strength training has not increased muscle mass, i.e. hypertrophy, it can be assumed that the effect is associated with the improvement in nerve–muscle coordination, which is expressed by the improvements in motor units muscle activity [24], [28]. In the group whose break lasted only 30 seconds, which did not allow a full recovery process after exercises, fatigue could have influenced the shaping effectiveness of the speed (power). Therefore, it may be assumed that K1 group could perform each series of exercises at a relatively higher level of relaxation.

Those tests were conducted on not trained people. The results of many works show that if one limb is trained, the other also is gaining in strength [5], [10], [29], [30]. However, we did not find that such a phenomenon is accompanied by muscle hypertrophy [15]. In addition, training of one limb can activate synaptic connections, which is responsible for strength development on the side which is not subjected to training. An example of such a mechanism is better coordination between synergists and inhibition of antagonists excitation [31].

5. Conclusion

1. The shortening of the rest between training series contributed to the relatively smaller increase in the values of muscle torque used to assess the effects of training.

2. The results do not confirm unambiguously the contralateral effects of power training. It should be noted, however, that the results reported determine the maximum power capacity of the knee joint, which is not subjected to training aimed at maximizing the growth of this characteristics. The increase observed (by 8%) in the muscle torque of left knee flexors in both groups was probably due to the stabilizing functions of those muscles.

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