Acta of Bioengineering and Biomechanics
Vol. 12, No. 1, 2010

Original paper

Evaluation of muscular stabilization ability during a static workout

MICHAŁ STANISZEWSKI*, CZESŁAW URBANIK, TADEUSZ STANISZEWSKI

Josef Pilsudski University of Physical Education in Warsaw, Poland.

The aim of this research was to determine the moving and stabilizing functions of selected groups of muscles during the process of static workout. 15 students of the Academy of Physical Education were tested in non-competitive training. Muscular torques achieved during flexing and extending big limb joints were used as the determinant of force. Comparative analysis of torque values achieved in passive stabilization (with support) and muscular stabilization (without support) in elbow and knee joints was carried out. The value of the force applied to the passively stabilizing element in a given measurement during the flexion of elbow and the extension of knee joint was tested. The results of these tests allowed us to learn the value of muscular torques and – after statistical analysis – the relationship between them in particular functions.

Key words: *muscles torques, isometric condition, passive stabilization, active stabilization*

1. Introduction

Because of the way they work, skeletal muscles perform moving and stabilizing functions. The former relate to the components of muscular forces affecting a degree of freedom within joints under the influence of all the forces independent of nervous system, i.e. any external forces in relation to kinetic apparatus, inertia forces and passive forces of stretching tissue. Stabilizing functions perform those components of muscular forces, which are counterbalanced by the agonists' muscle torques, i.e. the forces dependent on nervous system. Muscles or their parts are involved in the whole process of muscular stabilization by fulfilling stabilizing functions. This process means the imposition of active, muscular bonds on the presently unused degrees of freedom which are indispensable to any conscious human motor function [1].

The majority of the degrees of freedom in kinetic apparatus are not involved in normal human motor activity. Each technique of a given movement is effective, provided that the force involved has the optimum value, is applied at a defined point and acts in a precisely determined direction. Those conditions can be fulfilled only if the movement in certain joints is blocked, while a conjugate movement in desired joints is allowed. This means that imposing and releasing bonds in relation to the degrees of freedom in agreement with a planned movement define the control of a biomechanism. Joints have passive bonds in the form of ligaments and articular capsules and active ones in the form of muscles activated by nervous system. The imposition of active bonds is a dynamic process and an indispensable condition of the cooperation of muscle forces with the forces of external habitat. The blockade of the degrees of freedom not required at a given time becomes a vital condition in achieving any human movement. Any task can be performed only if muscular stabilization becomes an effect of intentional and coordinated action of nervous and kinetic systems. The effect of coordination must be a selective and synchronized activation of single muscles fulfilling stabilizing functions.

---

* Corresponding author: Michał Staniszewski, Josef Pilsudski University of Physical Education in Warsaw, ul. Marymoncka 34F m. 60, 01-813 Warszawa, Poland. E-mail: michal.staniszewski@awf.edu.pl

Received: October 21st, 2009
Accepted for publication: February 18th, 2010

The process of muscular stabilization runs along with the kinetic functions, i.e. the movement at a required number of the degrees of freedom. The number of stabilizing functions in any movement are limited. The lower the number of stabilizing functions, the higher the economy of a movement technique and the efficiency of bodily energy at the same time. Effective and highly efficient muscular stabilization could be one of the factors determining the quality of kinetic task [2], [3].

In most sport activities, the stabilizing functions are performed by muscle force. During research, especially under laboratory conditions, passive stabilizing is used [4]–[10] in order to eliminate muscle forces affecting considerably a kinetic function. Moreover, passive stabilization limits technique contribution to the resulting measurement.

It is difficult to arrive at a univocal answer confirming that passive stabilization increases the muscular ability in a stabilized joint. There is no proof for the correlation between muscle torque in flexors and extensors in a joint and the torque of muscle groups fulfilling the stabilizing function. The purpose of this study was to establish moving and stabilizing functions for the selected muscle groups during a static workout.

In the study, the following requirements had to be met:

- all the tests performed in accordance with the rules of measuring a muscle torque in static and standard angle positions in joints,
- the measurements for elbow and knee joint flexors and extensors carried out under conditions of their passive or active stabilization,
- the same conditions for all examinations,
- the measuring error not greater than 3%.

Hypothesis was based on the research, and the assumptions accepted was as follows: passive stabilization during measurement of muscle torque under static conditions increases the strength ability of the muscle groups tested.

2. Material and methods

The method used allowed us to establish the value of muscle torque in selected functions (flexing, extending) in human limb joints and to create the force topography of working muscle groups in relation to passive or active muscle stabilization.

Passive stabilization consisted in the measurement of muscle torque of all muscle groups tested (flexors and extensors of elbow, shoulder, knee and hip joints). Immobilizing supports and bands were used for adjacent body parts. For example, while measuring a passive stabilization of flexors and extensors of elbow joint (figure 1a), the arm was stabilized by support, and bands and frame stabilized shoulder girdle and trunk. Support was removed in active stabilization and the person examined had to keep the limb in the same position as with support, which was possible due to the stabilizing functions of upper extremity muscles (figure 1b). Knee joint flexors and extensors were treated similarly (figure 2a, b).

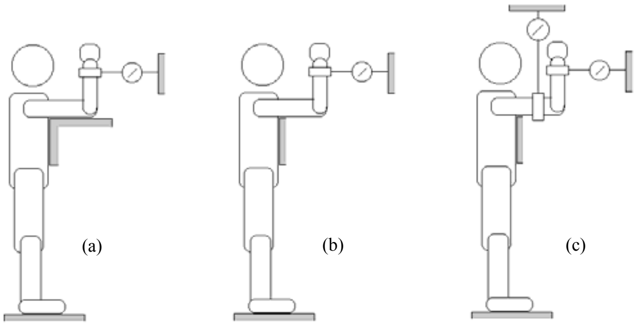

Fig. 1. Flexing in elbow joint:
(a) – passive stabilization, (b) – active stabilization,
(c) – measurement of external resistance torque

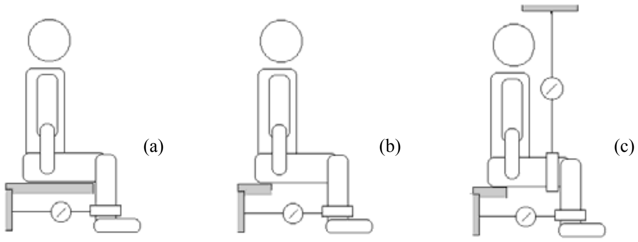

Fig. 2. Extending in knee joint:
(a) – passive stabilization, (b) – active stabilization,
(c) – measurement of external resistance torque

The muscle torques were measured on a special stand for the measurement of their static torques at the Biomechanics Laboratory of the Academy of Physical Education in Warsaw. The tests were carried out in the isometric work mode. Measurement positions were based on the analysis of professional literature. For the flexion in elbow joint (figure 1c) and the extension in knee joint (figure 2c) some additional measurements of the influence of arm and thigh forces, respectively, on passive stabilization (support) were taken.

For relative data, Student's *t*-test was used to compare the values of force instants achieved under passive or active stabilization. The difference of $p < 0.05$

was taken as significant. Calculations were done with the use of Statistica v.6 program (StatSoft, Inc. USA).

15 students of the University of Physical Education in Warsaw took part in the research, they were at an average age of 23 ± 1, their body mass was 78 ± 6 kg and the height – 178 ± 5 cm. At the time none of the students trained professionally.

3. Results

The table illustrates the average values of muscles torque instants achieved in the joints tested in comparison with those obtained in the method of stabilization and those from measurement.

Higher values of muscle torque instants in flexors rather than in extensors were recorded in the upper limb joints tested. The inverse relation was found in lower limb joints where extensors were stronger. Those relations are significant ($p < 0.05$) regardless of the kind of stabilization. In the experiment, the strongest group of muscles were hip extensors, while elbow extensors were the weakest. The values of the stabilizing torque in the extensors of knee joint were over twice as high as those in the flexors of elbow joint. All measurements of the types of stabilization showed statistically significant ($p < 0.001$) differences in the torque values achieved during passive and active stabilization.

One of the main aims of this study was to define the stabilizing functions of selected muscle groups. To achieve this, the passive stabilization was changed into muscle stabilization in four measurements. During the tests on elbow joint, to compare muscle torque values of flexors and extensors, the students examined did not change their positions; only the arm stabilizing support was removed.

The aim of the students examined was to achieve the same values as those during passive stabilization; the only difference was the position maintained by tension of relevant muscles. Average value for the group reached 72 ± 7 Nm, which was lower than that obtained during the tests with arm being stabilized. Muscle stabilizing abilities in this test are shown in figure 3 presenting the comparison of the torques obtained during passive stabilization with those in active stabilization. The results achieved during tests with passive stabilization were adopted as 100% value and marked in the diagram with a bold line. Columns show the point differences (in percent) between force instants with active stabilization. Lack of a passive stabilization of the arm meant that the results obtained were lower, on average, by 12.5% ($p < 0.001$).

Elbow joint extending, without passive stabilization of the arm, was tested in the similar condition to those of flexing in preceeding test. An average level set at 9% was higher than that during the tests with stabilization ($p < 0.001$). In the circumstances, thirteen students achieved higher values than in the previous test (figure 4), while two of them – lower values, but only by 1%.

Table. Average values (± SD) of muscle torques with function and limb distinction (all values in Nm)

Measurement \ Function	Upper limb				Lower limb			
	Elbow Flex.*	Elbow Ext.*	Shoulder Flex.	Shoulder Ext.	Knee Flex.*	Knee Ext.*	Hip Flex.	Hip Ext.
Passive stabilization	83 ± 5	56 ± 7	120 ± 12	112 ± 13	106 ± 18	260 ± 55	177 ± 24	463 ± 73
Active stabilization	72 ± 7	61 ± 9			135 ± 20	158 ± 28		
External resistance torque	76 ± 21					176 ± 23		

* The differences between passive and active stabilization on the level of significance $p < 0.001$.

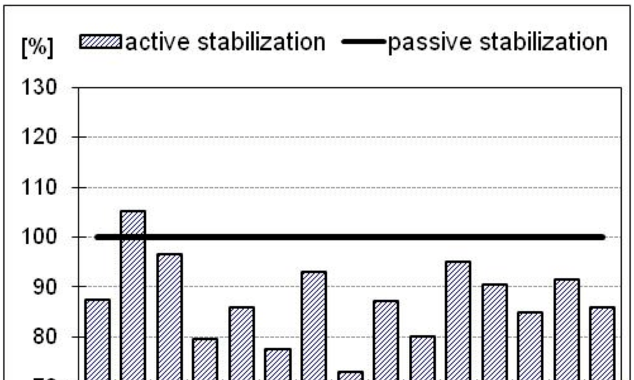

Fig. 3. Percentage values of torques of elbow flexors during passive and active stabilization

During the tests aiming at the recognition of the stabilizing ability of lower limb muscles to perform the bending and straightening functions in a knee joint, the person examined maintained the same position as during passive stabilization measurement. The

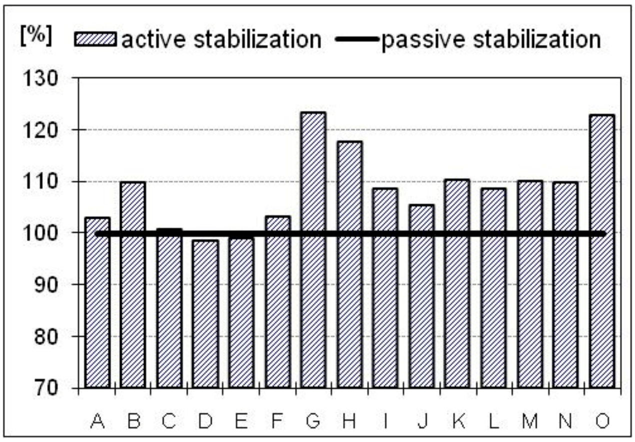

Fig. 4. Percentage values of torques of elbow extensors during passive and active stabilization

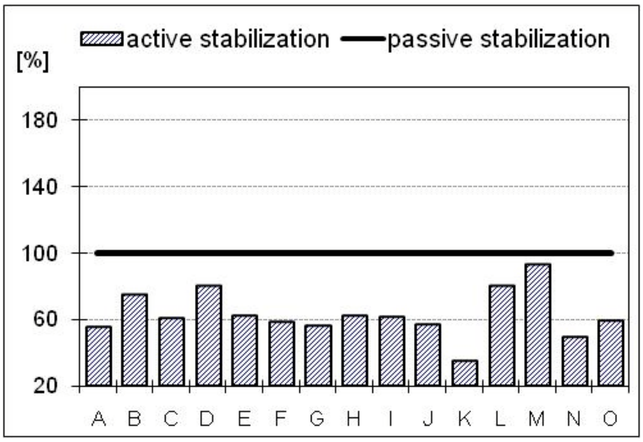

Fig. 6. Percentage values of torques of knee extensors during passive and active stabilization

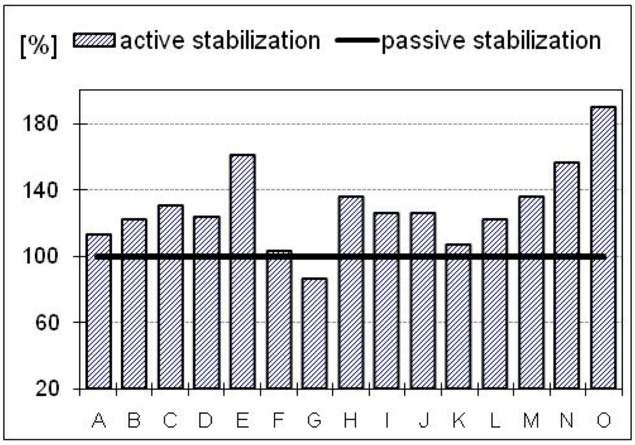

Fig. 5. Percentage values of torques of knee flexors during passive and active stabilization

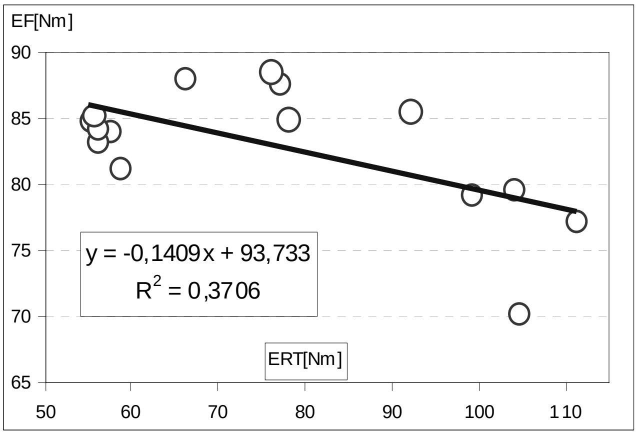

Fig. 7. Muscle torques of elbow flexors (EF) versus arm resistance value on support (ERT)

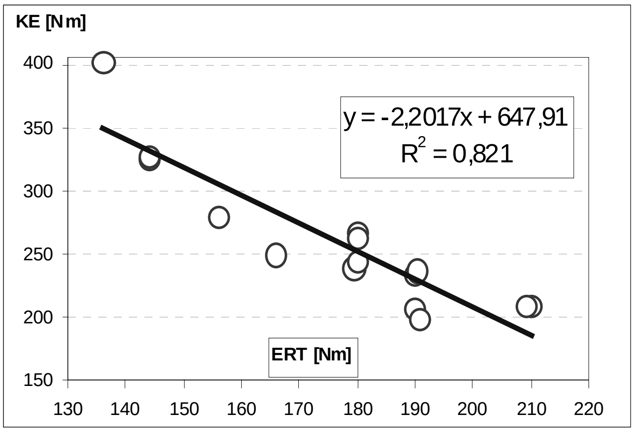

Fig. 8. Muscle torques of knee extensors (KE) versus thigh resistance value on support (ERT)

only difference during the second trial was the removal of a special thigh-stabilizing support that allowed free movement in a hip joint. A correct testing position was maintained by tensing relevant muscles. Flexors in the tests without stabilization achieved the values, an average, higher by 29 N than during the tests with stabilization. In contrast to elbow joint, where lack of stabilization allowed the achievement of better results during extension, much higher values of torques were observed for flexors. The comparison of both tests is shown in percentage points in figure 5. Bold line represents flexors during the tests with passive stabilization, shown as 100%, and columns show relative comparison of the results of the tests without stabilization. The values of flexor torques with muscle stabilization are superior ($p < 0.001$) and show an average level of 27%.

During knee joint straightening with muscle stabilization the average for the group was 158 ± 28 Nm. Analyzing figure 6 one can see higher values when a thigh is passively stabilized. The tests with muscle stabilization only revealed the results lower by 37% on average. The survey was undertaken in order to find the value of external resistance torque in the stabilizing point and to check whether this value is correlated with the torques of defined muscles. During elbow joint flexing the values of external resistance torques are 10% lower than the torque values of elbow joint flexors, whereas during knee joint straightening the external resistance torques are 30% lower than those of extensors in the same joint (the table).

The correlation for both tests was very high and negative, which means that the values compared are inversely proportional. Those correlations are stronger for the muscle torques of knee extensors (figure 8, $p < 0.001$) than for the muscle torques of elbow flexors (figure 7, $p < 0.02$).

4. Discussion

A definition of relation between testing position and the force applied during any motion and also a definition of relative significance of this force are very important issues from the point of view of Sports Biomechanics or practical training and widely understood ergonomics of human motion.

The main aim of this study was to establish the moving and stabilizing functions of selected muscle groups. During the tests on elbow joint, after the removal of arm stabilizing element, shoulder joint muscles take over the stabilizing functions. Analyzing the origins of muscles and their function [11], [12] it was proved that the front part of deltoid muscle, biceps and greater pectoral muscle were responsible for maintaining the arm at 90°. Biceps is a biarticular muscle, so apart from being an important shoulder joint muscle it also is the strongest flexor of elbow joint. This is why it is impossible to achieve maximum forces during flexing of a forearm while this muscle performs a stabilizing function. The removal of a passive support caused the results to drop by 12.5% on average.

The second cause of the above mentioned relation could be a muscle stabilization characteristic, described by KORNECKI [2] after a similar study. He proved that the maximum force with which those examined were pushing non-stabilized element with upper extremity, regardless of plane (horizontal or vertical), was only 75% of the force applied to stabilized element. This means that the process of combining active bonds with temporarily redundant degrees of freedom absorbs highly relevant part (around 25%) of human potential force. The differences in the force registered in mobile or immobile external setup testify to a percentage decrease of force in relation to maximum force that can be produced. When this difference becomes ever larger, the efficiency of muscle stabilization process, i.e. stabilizing function of muscles, is decreasing.

The straightening of elbow joint was studied in the same testing position as that during the bending of the same joint. Triceps and anconeus muscles are mainly responsible for this straightening. Despite the fact that the long head of triceps affects the function of shoulder joint, it does not take part in maintaining the tested position stable. It was interesting to check whether the removal of the element passively stabilizing the arm would influence the muscle torque values in this test. The result was that only three students achieved almost similar values in the test without passive stabilization to those participating in the test with passive stabilization. The rest of the students achieved, on average, the torque values by 9% higher. The removal of support induced the whole upper limb to be stabilized only in its proximal end (by muscles affecting the shoulder joint) and distal end (by the band connected to dynamometer). Under these conditions, during attempt to straighten the elbow joint, the parts of antagonistic muscles could get involved in the process of the widening of the joint angle.

During the tests on a knee joint, after the removal of a thigh-stabilizing element, hip joint muscles take over the stabilizing function. It is iliacus muscle, major lumbar muscle and rectus femoris muscle that are mainly responsible for maintaining the thigh at 90° angle. During flexion in the knee joint all the students tested achieved without passive stabilization the values that are, on average, by 30% higher. In this joint, the back group of thigh muscles and calf muscle (gastrocnemius), i.e. the muscles not taking part in maintaining the testing position of the thigh, are responsible for flexing. The removal of support induced the whole lower limb to be stabilized in proximal end (by muscles affecting the hip joint) and in distal end (by the band connected to dynamometer). A similar situation occurred during extension in the elbow joint. In the circumstances, during attempts to flex the knee joint, the parts of antagonistic muscles could get involved in the process of narrowing the joint angle.

The biggest drop in the value of force, after the removal of passive stabilization, was noted during tests while extending knee joint. The quadriceps muscle is responsible for extension in this joint. A front head of this muscle (rectus femoris muscle) is biarticular and apart from extending leg at knee joint it plays an important part in the process of stabilizing the thigh. That is why this stabilizing involvement of rectus femoris does not allow the quadriceps muscle to achieve the maximum force. The tests done after the removal of a passive stabilization of the thigh showed the results lower, on average, by 40% (maximum 65%). Much higher drop in the value of force, during lower leg extension rather than knee joint flexion, after the removal of stabilization is undoubtedly connected with the mass of lower extremity (19% of body mass), supported by muscles, being much greater than the mass of upper extremity (6% of body mass) [13].

It is worth mentioning that higher values of muscle torques achieved after the removal of passive stabilization were typical of the weaker group of given joint muscles. Thus, the extensors as a weaker muscle group of an elbow joint were characterized by higher values of torques during active stabilization and, similarly, the flexors of a knee joint had higher force values without passive stabilization.

Because both flexing of an elbow joint and extending of a knee joint involve biarticular muscles with the stabilizing function in both upper and lower extremities, those muscles achieve higher torque values during tests with passive stabilization. On the level of significance $p = 0.02$ it can be stated that lower values of muscle torques mean a stronger influence of arm or thigh muscles on stabilizing element. So, if the task is the maximum flexion in an elbow joint or extension in a knee joint, the higher value of external resistance torque can be indicative of a poorer coordination in the exercise performed.

5. Conclusions

The present research allows the following conclusions:

1. During attempts to extend elbow joints and to flex knee joints the bigger values of muscular torques are achieved in the measurements without passive stabilization.

2. Biarticular muscles controlling a stabilizing process in a proximal joint reduce the maximum values of forces in distal joint.

3. The values of muscle torques in elbow flexors and knee extensors are inversely proportional to the values of the forces acting on stabilizing element in a given movement.

4. Direct relation between the value of forces during flexing or extending in a given joint and the value of forces stabilizing muscle groups is not observed.

References

[1] FIDELUS K., *Biomechaniczne parametry kończyn górnych człowieka*, PWN, Warszawa, 1971.

[2] KORNECKI S., *Identyfikacja własności biomechanicznych procesu stabilizacji mięśniowej*, Studia i Monografie AWF, Wrocław, 1986, Zeszyt 11.

[3] KORNECKI S., MULARCZYK W., TRZCIŃSKI M., ZSCHORLICH V., *Dynamika procesu stabilizacji mięśniowej w obrazie EMG*, Materiały VIII Szkoły Biomechaniki, AWF, Warszawa, 1990, 185–202.

[4] BOBER T., HAY J.G., *Topografia siły mięśni kończyn człowieka*, Wychowanie Fizyczne i Sport, 1990, No. 3, 3–23.

[5] BUŚKO K., MADEJ A., MASTALERZ A., URBANIK CZ., WIT B., *Zależność między statycznym momentem sił a mocą kończyn dolnych rozwijaną w wybranych aktach ruchowych*, Acta Bioeng. Biomech., 2000, No. 1 (s1), 93–98.

[6] ELIASZ J., GAJEWSKI J., JANIAK J., TRZASKOMA Z., WIT A., *Przejawy siły mięśniowej – warunki i zasady jej pomiarów oraz znaczenie dla praktyki treningowej*, Teoria treningu, Sport Wyczynowy, 1994, No. 5–6, 23–25.

[7] FIDELUS K., OSTROWSKA E., URBANIK CZ., WYCHOWAŃSKI M., *Ćwiczenia laboratoryjne z biomechaniki*, AWF, Warszawa, 1996.

[8] HAKKINEN K., *Force production characteristics of leg extensor, trunk flexor and extensor muscles in male and female basketball players*, J. Sports Med. Phys. Fitness, 1991, No. 31, 325–331.

[9] TRZASKOMA Z., *Maksymalna siła mięśniowa i moc maksymalna kobiet i mężczyzn uprawiających sport wyczynowo*, Studia i Monografie No. 94, AWF, Warszawa, 2003.

[10] WYCHOWAŃSKI M., WIT A., TRZASKOMA Ł., GAJEWSKI J., ILNICKA L., STANIAK Z., *Maximal isometric torques of hip joint muscles*, Acta Bioeng. Biomech., 2002, No. 4 (s1), 628–629.

[11] BOCHENEK A., REICHER M., *Anatomia człowieka*, Tom I, Wydawnictwo Lekarskie PZWL, Warszawa, 2008.

[12] ORZECH J., *Siła mięśni człowieka. Monografia treningu siły mięśniowej*, Tom II, Sport i Rehabilitacja, Tarnów, 1998.

[13] FIDELUS K., MASTALERZ A., TOKARSKI T., *Spadek mocy w czasie ćwiczeń na równi pochyłej, ergometrze rowerowym i platformie dynamometrycznej*, Mat. XIII Szkoły Biomechaniki, Monografie AWF, Poznań, 1996, No. 330, 146–151.