Acta of Bioengineering and Biomechanics
Vol. 20, No. 2, 2018

Original paper
DOI: 10.5277/ABB-01092-2018-02

Evaluation of relationship between the results of selected tests for muscle strength assessment of the hip abductors

ELŻBIETA SZCZYGIEŁ[1]*, KATARZYNA KOTLA[1], AGATA MASŁOŃ[1], JOANNA GOLEC[1], DOROTA CZECHOWSKA[1], ROBERT STASZKIEWICZ[2], EMILIA KRZYWDA[1], EDWARD GOLEC[1]

[1] Orthopedic Rehabilitation Institute, Clinical Rehabilitation Division, Motor Rehabilitation Department, The Bronisław Czech University School of Physical Education, Cracow, Poland.
[2] Department of Biomechanics, University School of Physical Education in Kraków, Poland.

Purpose: The assessment of hip joint abductor muscle strength is most often carried out using a dynamometric test. However, both in clinical practice and literature, evaluation is performed by means of the single-leg half-squat or the amount of abduction movements performed in the hip joint. In this context, the question arises whether the results of individual tests are convergent. The aim of the study is to evaluate the relationship between strength of the hip abductor muscle measured by dynamometer, the single-leg-squat and the number of repetitions of the movements in time. *Methods:* A group of 35 students (20 women and 15 men) between 20 and 24 years old participated in the study. Each student was subjected to three tests assessing the condition of the hip and associated abductor muscles. Those included: assessment of hip joint abduction muscle strength in a dynamometric study, assessment of the number of abdomen movements performed lying on the side and standing, during a 30-second interval, and the single-leg-squat test. *Results:* Based on the tests conducted, a significant relationship was observed between the muscle strength measurement results for the left and right side in the dynamometric study and the number of hip abduction repetitions in 30 seconds and the single-leg-squat test. *Conclusions:* The obtained results indicate a significant relationship between the results of all the tests. In practice, this means that the tests can be used interchangeably.

Key words: *hip, muscle strength, functional testing*

1. Introduction

The basic feature of muscle tissue is the ability to generate strength. Muscle strength is the ability of muscles to produce maximum energy in order to overcome external resistance. Its source is muscle contraction resulting from stimuli. Depending on the relationship between the force generated by the muscle and its load, the static and dynamic (concentric and eccentric) activity of the muscle can be distinguished. The static action of the muscle occurs when the force released by the muscle and the acting load are equal. In the situation when the contraction force is greater than the acting load, concentric work takes place. When the force generated by the muscle is smaller than the external forces, eccentric activity of the muscle occurs. Many authors confirm the existence of dependence between the value of muscle strength generated and various types of disorders in the motion system. An example can be reports pointing out to the existence of a relationship between the weakening of the muscle strength of the hip abductor, and the development of the patellofemoral conflict or an increased risk of knee injuries [2], [9], [15], [17]. The confirmation of this phenomenon may be found in studies indicating that exercise programs aimed to strengthen the gluteus medius appear to have some effectiveness in the management of these disorders [3].

* Corresponding author: Elżbieta Szczygieł, Orthopedic Rehabilitation Institute, Clinical Rehabilitation Division, Motor Rehabilitation Department, Al Jana Pawła II 78, 31-571 Kraków, Poland. Phone: 609937736, e-mail: elzbietasz@gmail.com
Received: January 17th, 2018
Accepted for publication: April 23rd, 2018

Simple and popular tests can be used to assess muscle strength of the lower limb. Most often, a dynamometer is used to determine the value of hip joint abductor muscle strength [5], [10], [11]. Many authors are convinced that a measure of the strength of the hip abductor muscle may be the single-leg squat test [6], [21]. This test is particularly noteworthy, because standing on one lower limb is an indispensable element of the walking cycle [18]. Due to the fact that the exercise most often recommended to strengthen the abductors is side-lying hip abduction, one can expect that the number of abdomen movements performed at a given time can also be a measure of the strength of these muscles [8].

Bearing in mind the multiplicity of assessment methods of muscle strength of hip abductors or assessment of the strength of the hip abductor muscle, the question becomes whether the results of individual tests coincide.

The aim of the study was to evaluate the relationship between the strength of the hip abductor muscle measured by the dynamometer, the number of repetitions of abductions in time, and the single-leg -squat.

2. Materials and methods

The research material was a group of 35 students of the Bronisław Czech University of Physical Education in Cracow (20 women and 15 men). The age range of respondents oscillated between 20 and 24 years of age. Their characteristics are summarized in Table 1. The study participants did not report any pain in lower limbs and the spine.

Before participation, all participants were given a verbal explanation of the study, and they all signed a consent form.

Table 1. Demographic Characteristics of Participants

	Min	Mean	Max	SD
Age [years]	20	22.11	24	0.93
Height [m]	1.53	1.72	1.92	10.06
Weight [kg]	47	65.69	90	13.54
BMI [kg/m^2]	17.71	21.96	26.85	2.78

Each subject was subjected to three tests assessing the condition of the hip and related abductor muscles. These included: assessment of hip joint abduction muscle strength in a dynamometric study, assessment of the number of abduction movements performed in the side-lying position and standing position in a 30-second interval, and the single-leg-squat test.

2.1. Dynamometric measurement

The first research method used in the study was to measure the muscle strength of hip abductors using an electric dynamometer. The measuring station was located in the Bronisław Czech Academy of Physical Education in Cracow, at the Faculty of Physical Education and Sport in the Biomechanics Department.

Fig. 1. Dynamometric measurement – starting position

The subject's task was to perform one abduction movement in the hip joint. Before the start of the test, the subject was asked to take the appropriate measuring position (Fig. 1). It was necessary to block the possibility of movements in other joints during the measurement. The upper limb, opposite to the lower limb tested, was abducted at 90° and placed freely on a support. During the measurement, it was forbidden to hold on to anything. The second upper limb hung loosely along the body. A blockade to the side of the torso was also used to prevent lateral flexion of the torso. The lower limb (not being tested) was placed on a step, to completely relieve the limb being tested. After taking the appropriate position, the external force arm was measured with a ruler a ruler (50 cm) from the greater trochanter of the femur (the anatomical point being the center of the joint), towards the inside of the band (the direction of the external force). During the measurement, particular attention had to be paid to proper fixing of the band, which was perpendicular to the body segment, and the attached dynamometer. After measuring of the force arm, the subject was asked to abduct the lower limb. Dynamometric assessment was performed on both lower extremities. The measurement results were read from the computer. The next step was to calculate the moment of external force.

The following formula was used to calculate the moment of external force:

$$M_e = F_e * d_e$$

M_e – external force moment [Nm],
F_z – external force [N],
d_z – external force arm [m].

2.2. Single-leg squat test

Another test method was the single-leg squat test. The task of the subject was to move from the position of standing on both legs to standing on the stronger lower limb (better result in dynamometric evaluation) and perform a slow squat (bending the knee of the tested limb to about 60°), so that the hip joint of the untested limb was straightened, the knee joint bent to the maximum angle of 90°, arms bent to 90°, elbows straightened, hands joined together, one on top of the other. The subject had to perform the squat in a time no longer than 6 seconds [13].

The purpose of the test was to examine the behaviour of the pelvis and knee joint in the event that only one limb is loaded. A positive result of the test indicates weakness of the gluteus medius muscle [13]. During the observation of the subject, attention was paid to the overall condition of the muscles, i.e., whether the subject did not lose balance during the task and whether the squat was performed without haste. At the moment when the subject stood with one leg up, it was important to position the pelvis correctly. If the pelvis bent toward the unloaded side, it showed a positive Trendelenburg symptom. Occurrences of valgus or deformity of the knees, valgus of the ankle, internal rotation of the thigh, were treated as a movement disorder associated with the weakening of the gluteus medius muscle. It was required that the femur and tibia were positioned in a straight line that passes through the second metatarsal bone.

The score were as follows: 0, 1, 2 points, where:

2 points – lack of balance disorders, flexion of the hip > 60°, abduction/adduction of the hip <10°, valgus/varus of the knee <10°,

1 point – any 2 criteria from above met,

0 points – 1 criterion met or test subject lost balance.

2.3. Abduction of the hip joint in the sideways-lying position and in a standing position

The last test performed by the respondents was abduction in the hip joint in the side-lying position and in the standing position, within the interval of 30 seconds. The subject had to perform hip-joint abductions to the angle of approximately 40°, as quickly as they could.

The correct positions for the test:

Lying position: subject in sideways, lying position, limb tested in a neutral position in the hip joint, straightened in the knee joint, lower limb not tested slightly bent at the hip joint and knee joint to approximately 90°. One upper limb under the head, the other bent in the elbow joint, hand lightly rested against the couch.

Standing position: subject in an upright position, maintaining the natural curvature of the spine, body weight transferred to the lower limb not tested.

The examination of abduction was performed on both lower limbs. If during the movement of abduction, any additional movements appeared, for example: pelvic anteversion, or compensatory motion of the lumbar spine flexion, this was indicative of weak gluteus medius muscle. Breaks were scheduled between the tests, so that muscle fatigue would not affect the test results.

2.4. Statistical tools

Descriptive statistics (mean value, standard deviation) and statistical data analysis (Pearson's linear correlation coefficient, student *t*-test for independent samples) were used to develop the test results. In all tests carried out, a significance level of 0.05 was assumed.

3. Results

The results of the tests of hip joint abductor muscle strength using a dynamometer are presented in Table 2.

In order to evaluate the relationship between the results of measurements of the muscle strength of hip abductors measured with the use of a dynamometer and the number of repetitions of hip joint abduction within 30 seconds, Pearson's linear correlation coefficient was applied. The results are collected in Table 3.

On the basis of the conducted test, a significant relationship was observed between the muscle strength measurement results for the left and right side in the dynamometric study and the number of hip abduction repetitions in 30 seconds, for the left and right sides, both in standing and sideways-lying positions. A positive value of the correlation coefficient indicates that along with the increase in muscle strength in the dynamometric study, the number of repetitions of hip joint abduction increases.

The Pearson's linear correlation coefficient was used for the evaluation of the relationship between the meas-

Table 2. Results of abductor strength assessment for women and men

		Single-leg squat test [points]	Hip abductor muscle strength [Nm]		Hip abduction [number of repetitions]			
					standing position	standing position	lying position	lying position
			left side	right side	left side	right side	left side	right side
min	men	1.7	173.5	171.3	34.9	34.5	34.5	34.3
	women	1.3	109.9	114.7	31.7	31.5	30.8	30.9
SD	men	0.5	40.1	48.4	2.6	2.5	2.1	2.2
	women	0.7	42.1	39.7	3.5	3.1	3.9	3.0

Table 3. Results of the linear relationship between the strength of the hip abductor muscles in the dynamometric study and the number of hip joint abduction repetitions during 30 seconds in standing and sideways-lying positions

	Pearson's linear correlation coefficient	
	number of repetitions in standing	number of repetitions in lying positions
Strength of the hip abductor muscles – left side	.8018	.8113
	$N = 35$	$N = 35$
	$p = .000$	$p = .000$
Strength of the hip abductor muscles – right side	.8505	.8158
	$N = 35$	$N = 35$
	$p = .000$	$p = .000$

Table 4. Results of the linear relationship between the single-leg-squat test and the strength of hip abductor muscles in the dynamometric study (right and left side)

	Pearson's linear correlation coefficient	
	strength of the hip abductor muscles – left side	strength of the hip abductor muscles – right side
Single-leg-squat test	.5698	.5639
	$N = 35$	$N = 35$
	$p = .000$	$p = .000$

Table 5. Results of the linear relationship between the single-leg-squat test and the number of repetitions of hip joint abduction within 30 seconds in standing and lying (right and left side)

	Correlations			
	number of repetitions in standing	number of repetitions in standing	number of repetitions in lying	number of repetitions in lying
Single-leg-squat test	left side	right side	left side	right side
	.6921	.6964	.6943	.6703
	$N = 35$	$N = 35$	$N = 35$	$N = 35$
	$p = .000$	$p = .000$	$p = .000$	$p = ,000$

urements of the muscle strength of the hip abductors in the dynamometric test and the results of the single-leg squat test. The results are shown in Table 4.

Based on the test results, a significant relationship was found between the results of hip joint abduction muscle measurement in a dynamometric study for the right and left side and the result of single-leg-squat test. The positive value of the correlation coefficient indicates that along with the increase of muscle strength, the result obtained in the single-leg squat test increases.

The Pearson's linear correlation coefficient was used for the evaluation of the relation between the number of hip abduction repetitions in 30 seconds and the results of the single-leg squat test. The calculation results are collected in Table 5.

Based on the test results, a significant relationship was observed between the number of repetitions of hip joint abduction within 30 seconds in the lying and standing positions for the left and right sides and the results of the single-leg-squat test. A positive value of the correlation coefficient indicates that as the number of repetitions increases, the result obtained in the single-leg-squat test increases.

4. Discussion

The assessment of strength is a fundamental component of a physical examination. It is a challenge to apply valid and reliable measures to test the muscle strength in clinical conditions.

Examining hip abductor strength can be accomplished through various clinical tools and procedures in both non-load-bearing body positions, (side-lying or supine) and in a load-bearing body position (standing). Isokinetic dynamometry is recognized as the criterion standard for muscle strength assessment. These devices can either be handheld or stabilized. In the opinion of Agre and Krause using the more clinically practical handheld dynamometers does not guarantee reliable results [1], [12]. A number of limitations regarding the clinical application of the assessments have been reported: large force is required to achieve a "mechanical advantage" when testing the relatively strong lower limbs of young, physically active people; proper stabilization and orientation of the lower limb are difficult to maintain during a maximal contraction in the side – lying position. Specifically, it is difficult to keep the number of contraction/extension of the hip joint and the rotation of the pelvis consistent [19]. However, with a stabilized device, meaning that the examiner is not required to oppose the force of the patient, reliable results have been obtained [20]. Bearing these reports in mind, we used a stabilized dynamometer to carry out our research.

Widler et al. [22], using a dynamometer, assessed the influence of the body position (side-lying, supine, and standing), on the value of the generated force. The results obtained by them indicated that the side-lying body position was offering the most valid and reliable assessment of unilateral hip abductor strength. In our research, however, we chose the standing position, due to the fact that the non-load bearing testing position does not replicate the typical function of the hip abductor muscles under load.

We used functional tests in order to test muscle strength and power. One of them is the single-leg-squat test on a single lower limb. It also belongs to the load-bearing method category for assessing hip abductor strength. Many authors, a Crossley, determined that the single-leg squat was sufficiently reliable in diagnosing subjects with hip muscle weakness [6].

It can be assumed that people with greater strength of hip abductor muscles are able to perform a greater number of repetitions of abduction movement in the hip joint. Therefore, it seems that estimating the strength of the gluteus medius muscle by assessing the number of movements of hip joint abduction is justified. McBeth carried out research with 20 healthy runners (11 women and 9 men), to indicate the exercise that activates the gluteus medius muscle to the greatest extent. In order to compare the electromyographic activity produced by the gluteus muscle, they underwent three tests: abduction of the hip with a straight knee, abduction of the hip with a bent knee (clamshell exercise), hip joint abduction with the external rotation of the tested limb. The obtained results allowed the authors to state that the exercises for abduction of the hip joint with the straight knee are the best way to activate the gluteus medius muscle [14]. Based on these reports, in our work we took the abduction movements in the side-lying and standing position into account, with a straight knee joint.

The aim of our research was to assess the correlation between the results of the tests mentioned. In a small number of reports regarding the comparison of the results of tests measuring hip muscle strength, DiMattia et. al. [7] draw special attention. Their study involved 50 healthy participants (24 women and 26 men). All test subjects were tested for the strength of the hip abductor muscles using a dynamometer and the single-leg squat test. The author of the study assumed that people with greater strength of the hip abductor muscles have a smaller hip extension angle during these tests. However, the results obtained by him have shown that the usefulness of the single-leg-squat test in screening of hip-abductor strength in a healthy, physically active population, is limited. The results of this work are in opposition to the results obtained by DiMattia. In our study, a significant relationship was found between the results of hip joint abduction muscle measurement and the results of the single-leg squat test. A positive value of the correlation coefficient indicated that, along with the increase in the strength of the abductor muscles measured with the dynamometer, the result obtained in the squat test on one lower limb increases.

This means that people with a higher dynamometric measurement score gained more points in the single-leg squat test. It is worth noting that, in the DiMattia study, the muscle strength assessment was done in the side-lying position, using a handheld dynamometer. The discrepancy in the presented results suggests the need for further studies, involving a larger group of people. We also want to point out that the data obtained by us indicate the existence of a significant relationship between the results of all tests. A positive value of the correlation coefficient showed that along with the increase in the muscle strength of the hip abductor muscles in the dynamometric evaluation the number of repetitions of hip joint abduction increased in 30 seconds for the right and left sides, both in prone and standing positions.

Many authors suggest that muscle strength depends on the sex of the subjects. Ramskov et. al. tried to show the normative values of the eccentric strength of the hip abductor muscle in their work. They examined 831 (408 women, 423 men) healthy, beginner-level runners. The maximum strength of the abductor muscles was measured using a dynamometer. The results of their work showed a significant difference in the strength of the hip abductor muscle between women and men. Women obtained lower measurement results than men [16]. In the opinion of these authors, age and gender should be taken into account in determining normative values. These findings are in agreement with our studies. The results obtained by us indicate both a lower strength of the abductor muscles measured with a dynamometer, a smaller number of abduction movements and a lower number of points in the squat test in women, as compared to men.

Zeller showed that, compared to men, during a single-leg squat women display more pronounced valgus of the knee joint, and thus greater instability of the hip joint [23]. His study group consisted of 18 people (9 men and 9 women). To observe kinematic differences between women and men performing squats on one lower limb, the author used a three-dimensional camera system. His research showed that women had more pronounced adduction in the hip joint than men, (by about 4°). The symptom of increased adduction can be explained by difficulties in controlling the muscles of the hip, resulting from the weakening of the gluteus medius muscle. The reduced strength of this muscle was also expressed by the positive Trendelenburg symptom. The results of this study did not confirm this hypothesis. Although women had lower strength in dynamometric evaluation in comparison to men, which was manifested by a smaller number of repetitions of abduction, both with bent and straight knee joint, no differences were noticed in the squat test. The results obtained in this work, on the other hand, are consistent with Claiborne's findings. This author also showed the lack of differences between men and women in the quality of performing the single-leg squat [4]. 30 healthy people (15 women and 15 men) took part in his study. The frontal motion plane of knee joints was assessed using 3D motion analysis.

Certainly, our research is among the few works that relate to the comparative assessment of the results of individual tests assessing the strength of the hip abductor muscle. The weakness of our research was a small number of participants, and thus we see the need to continue our research on a larger sample size. Considering that there are reports about different response of men and women, the lack of homogeneity of the groups in this study makes it more difficult to generalize obtained results. Furthermore, it would be advisable if physical activity of study participants were taken into consideration.

5. Conclusions

The results obtained indicate a statistically significant relationship between the strength of the hip abductor muscle measured by a dynamometer, and the number of repetitions of abductions in time and the single-leg squat test. The study results indicates that with the increase of abductor muscle strength, the single-leg squat test results are getting better, and the number of hip abduction repetitions increases. The practical advantage of the obtained results is showing the possibility of using these tests interchangeably in clinical practice.

References

[1] AGRE J.C., MAGNESS J.L., HULL S.Z., WRIGHT K.C., BAXTER T.L., PATTERSON R., STRADEL L., *Strength testing with a portable dynamometer: reliability for upper and lower extremities*, Arch. Phys. Med. Rehabil., 1987, 68(7), 454–458.

[2] BOLGLA L.A., MALONE T.R., UMBERGER B.R., UHL T.L., *Comparison of hip and knee strength and neuromuscular activity in subjects with and without patellofemoral pain syndrome*, Int. J. Sports Phys. Ther., 2011, 6(4), 285–296.

[3] BOLING M.C., BOLGLA L.A., MATTACOLA C.G., UHL T.L., HOSEY R.G., *Outcomes of a weight- bearing rehabilitation program for patients diagnosed with patellofemoral pain syndrome*, Arch. Phys. Med. Rehabil., 2006, 87, 1428–1435.

[4] CLAIBORNE T., ARMSTRONG CH., GANDHI V., PINCIVERO D., *Relationship between hip and knee strength and knee valgus during a single leg squat*, J. Appl. Biomech., 2006, 22, 41–50.

[5] CLICK FENTER P., BELLEW J.W., PITTS T.A., KAY R.E., *Reliability of stabilised commercial dynamometers for measuring hip abduction strength: a pilot study*, Br. J. Sports Med., 2003, 37(4), 331–334.

[6] CROSSLEY K.M., ZHANG W.J., SCHACHE A.G., BRYANT A., COWAN S.M., *Performance on the single-leg squat task indicates hip abductor muscle function*, Am. J. Sports Med., 2011, 39, 866–873.

[7] DIMATTIA M.A., LIVENGOOD A.L., UHL T.L., MATTACOLA C.G., MALONE T.R., *What are the validity of the single-leg-squat test and its relationship to hip-abduction strength?*, J. Sport. Rehabil., 2005, 14, 108–123.

[8] DISTEFANO L.J., BLACKBURN J.T., MARSHALL S.W., PADUA DA., *Gluteal muscle activation during common therapeutic exercises*, J. Orthop. Sports Phys. Ther., 2009, 39(7), 532–540.

[9] HEWETT T.E., MYER G.D., FORD K.R., HEIDT R.S. JR., COLOSIMO A.J., MCLEAN S.G., VAN DEN BOGERT A.J., PATERNO M.V., SUCCOP P., *Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study*, Am. J. Sports Med., 2005, 33(4), 492–501.

[10] JACKSON S.M., CHENG M.S., SMITH A.R.JR., KOLBER M.J., *Intrarater reliability of hand held dynamometry in measuring lower extremity isometric strength using a portable stabilization device*, Musculoskelet Sci. Pract., 2017, 27, 137–141.

[11] KRAUSE D.A., NEUGER M.D., LAMBERT K.A., JOHNSON A.E., DEVINNY H.A., HOLLMAN J.H., *Effects of examiner strength on reliability of hip-strength testing using a hanheld dynamometer*, J. Sport Rehabil., 2014, 23(1), 56–64.

[12] KRAUSE D.A., SCHLAGEL S.J., STEMBER B.M., ZOETEWEY J.E., HOLLMAN J.H., *Influence of lever arm and stabilization on measures of hip abduction and adduction torque obtained by hand-held dynamometry*, Arch. Phys. Med. Rehabil., 2007, 88(1), 37–42.

[13] LIVENGOOD A.L., DIMATTIA M.A., UHL T.L., *Dynamic Trendelenburg: single-leg-squat test for gluteus medius strength*, J. Hum. Kinetics, 2004, 9(1), 60–61.

[14] MCBETH J.M., EARL-BOEHM J.E., COBB S.C., HUDDLESTON W.E., *Hip muscle activity during 3 side-lying hip-strengthening exercises in distance runners*, J. Athl. Train, 2012, 47(1), 15–23.

[15] NAKAGAWA T.H., MUNIZ T.B., DE MARCHE BALDON R., MACIEL C.D., DE MENEZES REIFF R.B., SERRAO F., *The effect of additional strengthening of hip abductor and lateral rotator muscles in patellofemoral pain syndrome: a randomized controlled pilot study*, Clin. Rehabil., 2008, 22, 1051–1060.

[16] RAMSKOV D., PEDERSEN M.B., KASTRUP K., LØNBRO S., JACOBSEN J.S., THORBORG ***K.***, NIELSEN R.O., RASMUSSEN S., *Normative values of eccentric hip abduction strength in novice runners: an equation adjusting for age and gender*, Int. J. Sports Phys. Ther., 2014, 9(1), 68–75.

[17] REIMAN M.P., BOLGLA L.A., LORENZ D., *Hip functions influence on knee dysfunction: A proximal link to a distal problem*, J. Sport. Reh., 2009, 18, 33–46.

[18] REIMAN M.P., BOLGIA L.A., LOUDON J.K., *A literature review of studies evaluating gluteus maximus and gluteus medius activation during rehabilitation exercises*, Phys. Theory Practice, 2012, 28(4), 257–268.

[19] SCOTT D.A., BOND E.Q., SISTO S.A., NADLER S.F., *The intra- and interrater reliability of hip muscle strngth assessment using a hanheld versus a portable dynamometer anchoring station*, Arch. Phys. Med. Rehabil., 2004, 85, 598–603.

[20] STARK T., WALKER B., PHILLIPS J.K., FEJER R., BECK R., *Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review*, PM R, 2011, 3(5), 472–479.

[21] WEEKS B.K., CARTY C.P., SEAN A., *Kinematic predictors of single-leg squat performance: a comparison of experienced physiotherapists and student physiotherapists*, BMC Musculoskelet. Disord., 2012, 25, 13, 207.

[22] WIDLER K.S., GLATTHORN J.F., BIZZINI M., IMPELLIZZERI F.M., MUNZINGER U., LEUNING M., MAFFIULETTI N.A,. *Assessment of hip abductor muscle strngth. A validity and reliability study*, J. Bone Surg. Am., 2009, 91, 2666–2672.

[23] ZELLER B.L., MCCRORY J.L., KIBLER W.B., UHL T.L., *Differences in kinematics and electromyographic activity between men and women during the single-legged squat*, Am. J. Sports Med., 2003, 31, 449–456.