

## 1st World Congress on Health and Martial Arts in Interdisciplinary Approach, HMA 2015

# Fatigue resistance of thigh muscles in sport games players

Inese Pontaga<sup>1</sup>, Janis Zidens<sup>2</sup>

<sup>1</sup> Department of Anatomy, Physiology, Biochemistry and Hygiene, Latvian Academy of Sports Education, Latvia

<sup>2</sup> Department of Sport Games of Latvian Academy of Sports Education, Latvia

## Abstract

**Background and Study Aim.** Changed thigh muscles action balance can cause sports injuries. The aim of our investigation was the knowledge about effect of thigh muscles fatigue resistance on the knee flexor (Fl)/ extensor (Ext) muscles mean work (W) and power (P) ratio.

**Material and Methods.** Fourteen amateur male handball players participated. The tests were carried out by a dynamometer system using the knee isokinetic flexion–extension movements at angular velocity of 90°/s (five repetitions) and 240°/s (20 repetitions) by the concentric contractions. The mean thigh muscles W, P and Fl/Ext muscles mean W and P ratios were calculated for the first ten and last ten repetitions. The correlation between the thigh muscles peak torques ( $\tau_{max}$ ) at the velocity of 90°/s, 240°/s and W, P at the first and last ten repetitions was determined.

**Results.** Mean W produced by the knee Fl in the last ten movements was smaller than in the first ten motions ( $p < 0.02$ ). The knee  $W_{Fl}/W_{Ext} = 0.69$ ;  $P_{Fl}/P_{Ext} = 0.65$  in the last ten motions were lower than in the first ten movements:  $W_{Fl}/W_{Ext} = 0.73$ ;  $P_{Fl}/P_{Ext} = 0.71$  ( $p < 0.002$ ). Therefore the knee joint trauma may occur more probably after fatigue appearance. The positive correlation between thigh muscles  $\tau_{max}$  and W, P in the first ten and last ten knee movements ( $p < 0.01$ ) confirms that strength training of muscles will improve not only the maximal strength but also the fatigue resistance.

**Conclusion.** The significant positive correlation between thigh (hamstrings and quadriceps femoris) muscles peak torques and the mean work and power of the same muscles in the first ten and last ten knee *flexion–extension* movements ( $p < 0.01$ ) confirms that the strength training of these muscle groups will improve not only the maximal strength but also the fatigue resistance of these muscles.

**Key words:** *flexion–extension* movement • handball • knee • strength and power balance

**Published online:** 17 September 2015

**Copyright:** © 2015 the Authors. Published by Archives of Budo

**Contributors:** Inese Pontaga, Janis Zidens conceived the study design. Inese Pontaga, Janis Zidens collected the data. Inese Pontaga analysed the data. Inese Pontaga, Janis Zidens prepared the manuscript. Inese Pontaga secured the funding.

**Funding:** This study was supported by nobody.

**Conflict of interest:** Authors have declared that no competing interest exists

**Ethical approval:** The experiments reported in the article were undertaken in compliance with the current laws of the Latvia. The study was performed in accordance with the standards of the Ethics Committee of the Latvian Council of Sciences.

**Provenance and peer review:** Under responsibility of HMA Congress

**Corresponding author:** Inese Pontaga, Department of Anatomy, Physiology, Biochemistry and Hygiene, Latvian Academy of Sports Education, Brivibas Street 333, Riga, LV 1006, Latvia; e-mail: [inese.pontaga@lspa.lv](mailto:inese.pontaga@lspa.lv)

**Open Access License:** This is an open access article distributed under the terms of the Creative Commons Attribution-Non-commercial 4.0 International (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits use, distribution, and reproduction in any medium, provided the original work is properly cited, the use is non-commercial and is otherwise in compliance with the license

**Cite it:** Pontaga I, Zidens J. Fatigue resistance of thigh muscles in sport games players. In: Kalina RM (ed.) Proceedings of the 1st World Congress on Health and Martial Arts in Interdisciplinary Approach, HMA 2015, 17–19 September 2015, Czestochowa, Poland. Warsaw: Archives of Budo; 2015. p. 165–169

## INTRODUCTION

The influence of knee flexor (hamstrings) and extensor (quadriceps femoris) muscles fatigue resistance on knee muscles strength ratio during *flexion–extension* movements is not investigated in wide scale. Only few authors are investigated a relationship between the knee flexor and extensor muscles strength balance and an occurrence of injuries for healthy athletes. For example, Knapik et al. [1] revealed that the thigh muscles strength imbalance measured at fast velocity of movements by isokinetic dynamometer is associated with injuries. The predisposing factors to injury are [2]: changed muscles agonists/antagonist's strength, work and power balance, lack of flexibility in the joint, insufficient warm-up before exercises and fatigue of muscles.

An investigation method of the thigh muscles strength (torques produced by the muscles agonists and antagonists) balance and the same muscles mean work and power balance is the isokinetic dynamometry. A mean value for the knee flexor/extensor (hamstrings/ quadriceps femoris) muscles peak torques ratio in concentric contraction of the muscles is approximately 60% at slow angular velocity of movement of 30°-60°/s [3-5]. The value of this ratio increases with the growth of the velocity of movements, and it is close to 80% at the fast velocity of 240°-300°/s [6-9]. Pontaga I. [10] determined that the mean knee flexor/ extensor muscles peak torques ratio of male students trained in sport games (the mean age  $24,3 \pm 4,5$  years) at the medium angular velocity of movements of 100°/s is  $61\% \pm 7\%$ , but at the high velocity of 200°/s this ratio is  $70\% \pm 9\%$ . These results agree with the data of Calmels et al. [3], they obtained the ratio 55-60% at the slow velocity of 60°/s and 63% at fast angular velocity of movements of 240°/s. Changes of the knee flexor/ extensor muscles peak torques, mean work and power ratio due to repeated knee *flexion–extension* movements and caused by training or play match are not known.

If the hamstrings muscles are too weak in comparison with the quadriceps femoris muscle, it can change the muscles action balance and to create additional mechanical stresses on the knee anterior cruciate ligament (ACL) [11]. These muscles partially compensate the knee ACL ligaments functions: they restrict the anterior movement of a tibia relative to a femur and provide resistance to valgus and varus deformations of the leg in the knee joint, as well as, to rotation of the tibia [2]. Therefore weakness of the hamstring muscles can promote the knee joint trauma occurrence in sport activities.

Isokinetic muscle endurance is the capacity of a muscle to perform work, and fatigue is measured as a

decline in work production over a series of consecutive contractions [12]. Total work performed over several isokinetic contractions is a valid indicator of the endurance capacity of a single muscle group. Kannus [13] showed that the total work performed during a 25 repetition isokinetic test and the total work performed for the final five of the 25 repetitions were as significant and consistent as peak torque for the measurement of muscle endurance capacity.

The aim of our investigation was the knowledge about effect of thigh muscles fatigue resistance on the knee flexor/ extensor muscles mean work and power ratio.

## MATERIALS AND METHODS

### Participants

Fourteen amateur male athletes played in Premium league team were informed of possible test risks and voluntarily participated in the investigation. Their training experience in team handball ranged from seven to ten years. These athletes trained five times per week and played regularly on the weekends. The study was performed in accordance with the standards of the Ethics Committee of the Latvian Council of Sciences. All knee joints of the athletes were injury free and painless during the investigation. The mean age, body height, body mass and body mass index of the tested athletes equaled:  $19 \pm 2$  years,  $187 \pm 5$  cm,  $79 \pm 7$  kg and  $22.52 \pm 1.51$  kg/m<sup>2</sup>.

### Procedures

The tests were performed using the dynamometer system REV-9000 (Technogym, Gambettola, Italy) in the isokinetic knee *flexion–extension* movements at the medium angular velocity 90°/s (degrees per second) and high velocity 240°/s. The range of movements was from 10° in the knee extension to 90° in flexion. The person was placed in the positioning seat with the hip at an angle of 120° of flexion. The hip and trunk were fixed by stabilizing straps. The support lever was attached at the point between the upper two thirds and the lower third of the shin. The athlete was fixed in position after adjustment of the depth of the seat, the height of the dynamometer and the length of support lever to be aligned with a prolonged virtual rotation axis of the knee. The rotation axis of the knee joint was determined as a line passing through the femoral condyles. The measurements were corrected for the effects of gravity.

Passive *internal–external* rotation motions in the knee joint were performed for 90 s at an angular velocity of 120°/s just before the investigation. The athletes were given detailed verbal instructions of the procedures and performed five submaximal warm-up repetitions before the test.

The test began with the knee extension from 90° of the range of movements – extreme flexion position. The knee isokinetic concentric *flexion–extension* movements were tested at angular velocity values of 90°/s and 240°/s. The movements were repeated five times at the velocity of 90°/s and 20 times at the velocity of 240°/s. Subjects were verbally encouraged to maximally move the extremity “as hard and as fast as possible” during concentric testing. The passive *flexion–extension* motions in the knee joint were performed for 90 s at the angular velocity of 120°/s between tests of different velocities.

Peak torque ( $\tau_{max}$ ) values (N·m) of the knee flexor and extensor muscles were obtained from the best repetition (greatest peak torque). The mean work (W) and mean power (P) of the knee flexor and extensor muscles of the both legs were determined for the first ten and last ten repetitions of knee *flexion - extension* movements at an angular velocity of 240°/s. The mean work and power ratios of the knee flexor/extensor muscles were calculated for the first ten and last ten repetitions of movements.

**Statistic**

Mean values and standard deviations for all characteristics were calculated. A dependent t-test for paired data groups was employed to determine differences between the mean W, mean P, and mean W and P ratios of the knee flexor/extensor muscles in the first ten and last ten repetitions of the knee *flexion–extension* movements at the velocity of 240°/s. The differences were considered statistically significant at  $p < 0.05$ . The linear correlation analysis was used to determine the relationships between the peak torques of knee flexor and extensor muscles at both velocities (90°/s and 240°/s) and the mean work and power of the same muscles in the first ten and last ten repetitions of movements at the fast angular velocity of 240°/s. Microsoft Excel 2007 was used to perform all statistical procedures.

**Table 3.** The correlation coefficients between the peak torque ( $\tau_{max}$ ) and mean work or power of knee extensor (Ext) and flexor (Fl) muscles developed by the same muscles in the first ten and last ten repetitions of knee flexion – extension movements at the velocity of 240°/s ( $p < 0.01$ )

Velocity of movement	Peak torque	Mean	Work (J)	Mean	Power (W)
	(N·m)	First 10 repetitions	Last 10 repetitions	First 10 repetitions	Last 10 repetitions
90°/s	$\tau_{max}$ (Ext)	0.65	0.56	0.65	0.56
	$\tau_{max}$ (Fl)	0.62	0.62	0.59	0.47
240°/s	$\tau_{max}$ (Ext)	0.49	0.63	0.76	0.81
	$\tau_{max}$ (Fl)	0.49	0.55	0.62	0.67

**RESULTS**

The mean work and power of the knee extensor muscles in the first ten and last ten flexion – extension movements did not differ significantly (Table 1). The mean power of knee flexor muscles in the first ten and last ten movements did not differ significantly. The mean work of knee flexor muscles in the last ten movement repetitions was significantly smaller than in the first ten movements ( $p < 0.02$ ).

**Table 1.** The mean work (W) and power (P) of knee extensor (Ext) and flexor (Fl) muscles in the first ten and last ten repetitions of the knee flexion – extension movements at the velocity of 240°/s

Repetitions	First ten	Last ten	Sign. of difference
$W_{Ext}$ (J)	127 ± 19	128 ± 17	$p > 0.05$
$P_{Ext}$ (W)	235 ± 47	240 ± 36	$p > 0.05$
$W_{Fl}$ (J)	92 ± 11	88 ± 9	$p = 0.02$
$P_{Fl}$ (W)	161 ± 31	156 ± 24	$p > 0.05$

The knee flexor/extensor muscles mean work and power ratios were lower in the last ten movements in comparison with the first ten,  $p < 0.002$  (Table 2).

**Table 2.** The mean work (W) and mean power (P) ratio values of knee Fl/Ext muscles in the first ten and last ten repetitions of the knee flexion – extension movements at the velocity of 240°/s

Repetitions	First ten	Last ten	Sign. of diff.
$W_{Fl}/W_{Ext}$	0.73 ± 0.11	0.69 ± 0.10	$p = 0.002$
$P_{Fl}/P_{Ext}$	0.71 ± 0.11	0.65 ± 0.09	$p = 0.001$

Positive significant correlations were determined between the  $\tau_{max}$  and mean W or P of the knee flexor and extensor muscles developed by the same muscles in the first ten and last ten repetitions of knee *flexion–extension* movements at the angular velocity of 240°/s (correlation coefficients varied from 0.49 to 0.81,  $p < 0.01$ ) (Table 3).

The correlation coefficients between  $\tau_{\max}$  of the knee muscles measured at the medium (90°/s) or fast (240°/s) angular velocity and mean work of the same muscles was similar ( $r$  varied from 0.49 to 0.65). The correlation coefficients between  $\tau_{\max}$  of the knee muscles at the angular velocity of 240°/s and mean power of the same muscles were closer ( $r$  varied from 0.62 to 0.81) in comparison with the correlations between the  $\tau_{\max}$  of these muscles measured at the angular velocity of 90°/s and mean power produced by the muscles ( $r$  varied from 0.47 to 0.65).

## DISCUSSION

From our data training in team handball causes better strength and fatigue resistance development in the knee extensor muscles (quadriceps femoris) in comparison with the knee flexors (hamstrings) in many players. Fatigue of the knee flexor muscles appears faster than of the extensor muscles because the mean work produced by the knee flexors in the last ten flexion – extension movement repetitions was significantly smaller than in the first ten motions ( $p < 0.02$ ). This causes significant decrease of the knee flexor/ extensor muscles mean work and power ratios in the last ten motions ( $W_{\text{Fl}}/W_{\text{Ext}} = 0.69$ ;  $P_{\text{Fl}}/P_{\text{Ext}} = 0.65$ ) in comparison with the first ten knee flexion–extension movements ( $W_{\text{Fl}}/W_{\text{Ext}} = 0.73$ ;  $P_{\text{Fl}}/P_{\text{Ext}} = 0.71$ ),  $p < 0.002$ . Due to the hamstrings muscles lower fatigue resistance and relative weakness in work and power production in comparison with the quadriceps femoris muscle after many repetitions of the knee flexion–extension movements, the thigh muscles action balance is changed, additional mechanical stresses on the knee anterior cruciate ligament (ACL) are created and this can be a reason of the injury of ACL [11]. Therefore the knee joint trauma may occur more probably after many knee flexion–extension movement repetitions or in the end of the game or training in handball players.

The hypertrophy of hamstrings can appear as a compensatory reaction to knee injuries. For example, the greater knee flexor/ extensor peak torques ratio (60–70%) is observed in the operated leg of male sport games players six to 13 months after the knee ACL reconstructive operation in comparison with the contralateral legs' muscles ratios without special training exercises of hamstrings [14], as well as, in comparison with the average ratio value of uninjured people  $61\% \pm 7\%$  in the concentric/ concentric contractions of the thigh muscles [10]. This can be explained by the quadriceps femoris muscle relative weakness and the hamstrings hypertrophy to compensate partially

the ACL functions to restrict the anterior movement and rotation of the tibia in the operated leg.

One commonly held belief is that muscle hypertrophy induces increased strength at the expense of fatigue resistance or strength endurance, which is not confirmed by research data [15]. Rube and Secher [16] determined that a five-week program of static training using maximal isometric knee extensions increased fatigue resistance as tested by maximal extensions every fifth second. When the test was performed bilaterally, improvements were observed only in groups that had trained bilaterally, but improvement in unilateral fatigue was evident only in the group that had trained unilaterally with that leg. This investigation supports the positive effect of static strength training on fatigue resistance. These results agree with our data that the increase in the  $\tau_{\max}$  values of the knee flexor and extensor muscles at medium (90°/s) and fast (240°/s) velocity of movements positively correlated with the mean  $W$  and  $P$  of the same muscles in the first ten and last ten isokinetic knee flexion–extension movements at the velocity of 240°/s. Therefore, preventive knee flexor muscle strength training programs for handball players are recommended. This training would cause increase the knee flexor/extensor muscles peak torques, mean work and power ratios not only in the first to tenth repetition of the knee flexion – extension movements, but also in greater amount of movements or improve the fatigue resistance of hamstrings.

## CONCLUSIONS

Fatigue of the knee flexor muscles (hamstrings) appears faster than of the extensor muscles (quadriceps femoris) because the mean work produced by the knee flexors in the last ten flexion–extension movement repetitions was significantly smaller than in the first ten motions ( $p < 0.02$ ). The knee flexor/ extensor muscles mean work and power ratios in the last ten motions ( $W_{\text{Fl}}/W_{\text{Ext}} = 0.69$ ;  $P_{\text{Fl}}/P_{\text{Ext}} = 0.65$ ) were significantly lower in comparison with the first ten knee flexion–extension movements ( $W_{\text{Fl}}/W_{\text{Ext}} = 0.73$ ;  $P_{\text{Fl}}/P_{\text{Ext}} = 0.71$ ),  $p < 0.002$ . Therefore the knee joint trauma may occur more probably in the end of the game or training.

The significant positive correlation between thigh (hamstrings and quadriceps femoris) muscles peak torques and the mean work and power of the same muscles in the first ten and last ten knee flexion–extension movements ( $p < 0.01$ ) confirms that the strength training of these muscle groups will improve not only the maximal strength but also the fatigue resistance of these muscles.

## HIGHLIGHTS

The knee flexor/extensor mean work and power ratios decrease due to faster fatigue of hamstrings in comparison with quadriceps femoris is observed in sport game players. This can cause knee joint trauma. Strength training of hamstrings will improve the fatigue resistance of these muscles.

## ACKNOWLEDGEMENTS

The authors would like to sincerely thank all the team handball players who gave up their time to take part in the study, and their coaches who encouraged the athletes to do that.

## REFERENCES

1. Knapik JJ, Bauman CL, Jones BH et al. Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *Am J Sports Med* 1991; 19: 76-80
2. Whiting WC, Zernicke RF. *Biomechanics of Musculoskeletal Injury*. Human Kinetics, Champaign; 1998
3. Calmels PM, Nellen M, van der Borne I et al. Concentric and eccentric isokinetic assessment of flexor – extensor torque ratios at the hip knee, and ankle in a sample population of healthy subjects. *Arch Phys Med Rehabil* 1997; 78: 1224-1230
4. Kellis E, Baltzopoulos V. Isokinetic eccentric exercise. *Sports Med* 1995; 19: 202-222
5. Nosse LJ. Assessment of selected reports on the strength relationship of the knee musculature. *J Orthop Sports Phys Ther* 1982; 4: 78-85
6. Osternig LR. Isokinetic dynamometry: implications for muscle testing and rehabilitation. *Exerc Sport Sci Rev* 1986; 14: 45-80
7. Francis K, Hoobler T. Comparison of peak torque values of the knee flexor and extensor muscle groups using Cybex II and Lido 2,0 isokinetic dynamometers. *J Orthoped Sports Phys Ther* 1987; 8: 480-483
8. Alexander MJL. Peak torque values for antagonist muscle groups and concentric and eccentric contraction types for elite sprinters. *Arch Phys Med Rehabil* 1990; 71: 334-339
9. Chan KM, Maffulli N, Korkia P et al. *Principles and Practice of Isokinetics in Sports Medicine and Rehabilitation*. Williams & Wilkins Asia – Pacific Ltd. 1996
10. Pontaga I. Hip and knee flexors and extensors balance in dependence on the velocity of movements. *Biol Sport* 2004; 21: 261-272
11. Kannus P, Jarvinen M. Knee flexor/ extensor strength ratio in follow - up of acute knee distorsion injuries. *Arch Phys Med Rehabil* 1990; 71: 38-41
12. Dvir Z. *Isokinetics. Muscle Testing, Interpretation, and Clinical Applications*. Edinburgh: Church-Livingstone; 2004
13. Kannus P. Normality, variability and predictability of work, power, and torque acceleration energy with respect to peak torque in isokinetic muscle testing. *Int J Sports Med* 1992; 13: 249-256
14. Pontaga I, Larins V. Thigh muscles functional condition of sportsmen after knee anterior cruciate ligament injury and operation. *Proceedings of the Latvian Academy of Sciences* 2006; 60(5/6): 190-193
15. Gardiner PF. Muscle property changes in strength training. In: *Advanced neuromuscular exercise physiology*. Human Kinetics, printed in USA; 2011: 161-174
16. Rube N, Secher NH. Effect of training on central factors in fatigue following two and oneleg static exercise in man. *Acta Physiol Scand* 1990; 141: 87-95