SELECTED ISOKINETIC TESTS IN KNEE INJURY PREVENTION

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ABSTRACT: Ensuing from isokinetic measurements, the conventional Hcon/Qcon ratio of muscle balance is used as an index for comparing proper relations between the values of strength of knee flexors and extensor muscle. Its abnormal values might indicate pathology of the musculotendinous complex. The aim of the study was to present the possibility of using this ratio as one of the objective identifiers enabling the assessment of knee injury risk in sports. All participants (n=48) were divided into 3 groups: group A (n=16, healthy competitors), group B (n=16, athletes with minor injuries), group C (n=16, competitors with serious injuries), depending on the degree of knee injury. All subjects performed an isokinetic test for knee extensors and flexors at angular velocities of 60°/s and 120°/s. Average peak torque (APT) value of knee flexors and extensors, and the value of Hcon/Qcon ratio was analyzed. Both values were calculated in relation to body mass (Nm/kg). Bilateral comparison of isokinetic test parameters confirmed the decrease of quadriceps muscle strength values for the injured extremity in groups B and C. Statistically significant difference was noted for Hcon/Qcon ratio between group A and C, as well as B and C. Hence, the value of conventional Hcon/Qcon ratio can be used for the prevention of sports related injuries

KEY WORDS: injury prevention, Hcon/Qcon ratio, Isokinetic tests, Muscle dysbalance

INTRODUCTION

Comprehensive injury prevention is a complex process. It is an effort of a multidisciplinary medical team whose work is aimed at the reduction of injury risk. On one hand, it depends on precise medical diagnosis; on the other, it requires comprehensive rehabilitation. What is more, proper selection of intensity and load used during the rehabilitation process and sport training is important. In this aspect, the knowledge and experience of trainers helps to prepare and implement proper training which reduces the risk of injuries, especially those related to overtraining. Athletes' awareness, their motivation and commitment in fulfilling the suggested preventive tasks are also important factors related to injury prevention [7,11,14].

Factors and causes related to injury prevalence:

1. sports discipline (type of work),
2. improper use of equipment, environmental conditions,
3. training errors and insufficient conditioning level,
4. level of sport advancement,
5. previous injuries (joint instability),
6. sex,
7. psychological (mental) status,
8. anatomic, structural, biomechanical factors.

Many authors stress the importance of proper balance of antagonist muscles when participating in physical effort [16,19,21]. Muscle imbalance around a joint or body segment can lead to the lack of proper control over body movement. Knapik et al. confirmed that contralateral imbalance of hamstring group higher than 15% increases risk of injury 2,6 times [3].

Isokinetic testing provides precise evaluation of muscle strength balance. The H/Q ratio between knee extensors and flexors registered during concentric muscle contraction is one of the important parameters used for evaluation. In literature this ratio is known as the conventional Hcon/Qcon ratio and it is calculated as knee flexors peak torque divided by peak torque of knee extensor muscles. Knee extensors' peak torque value should exceed knee flexors PT value in 3:2 ratio [28]. Hcon/Qcon ratio depends on the velocity of the movement of the tested limb, as well as on the testing position and on the evaluated group [2,29]. Many authors provide the value of 0.6 as a normative for Hcon/Qcon ratio for 60°/s which increases up to 0,8 with increased movement velocity [20,27]. Heiser et al. conc-

luded that different Hcon/Qcon values can increase the risk of soft tissue or muscle injury [10]. The higher the values of Hcon/Qcon the better functional capability of knee flexors to stabilize the knee joint [9]. Increased knee stability can prevent and reduce the risk of injury [17].

On the basis of the Hcon/Qcon ratio value one can estimate the risk of injury to musculotendinous unit and then implement proper prevention activities during physical effort [5,12,13,15,19].

This study aims at presenting the possibilities of using isokinetic testing for muscle balance assessment, as one of the predicators enabling the evaluation of knee injury risk in sports.

MATERIALS AND METHODS

48 athletes representing various sport disciplines participated in this study. All participants were divided into 3 groups: A, B and C. Group A consisted of 16 healthy subjects, where medical interview did not reveal any symptoms of even minor musculoligamentous injuries. Group B consisted of 16 subjects with minor injuries (knee sprains, contusions, hamstrings sprains – without other clinical symptoms). Finally, group C comprised 16 subjects with significant injuries (meniscus, cartilage and ligamentous injuries), clinically confirmed during e.g. arthroscopic procedures. All participants signed formal consent and were informed about the goal and scope of the evaluation. Isokinetic testing was performed from January to June 2006.

Anthropometric characteristics of participants are detailed in Table 1.All participants had their knees dynamically tested for concentric work. The test was performed bilaterally for 5 repetitions (flexion and extension) at 60°/s and 10 repetitions at 120°/s. Tested ROM was 90° from complete extension to 90° flexion. Tests were performed at the Physiotherapy Center "Fizjofit" in Gliwice.

The distal end of the lower limb above lateral malleouls was strapped to the moving arm of the isokinetic device by a velcro strap, allowing for unrestricted physiological movement. Axis of movement of the arm was aligned with the axis of knee movement. Proximal segment of the thigh was stabilized by a velcro strap, pelvic and trunk were also stabilized properly. During testing upper limbs were placed across chest. Patients were verbally encouraged and motivated during the testing, according to the accepted methodology [4].

Before testing, all subjects participated in a warm-up session, which consisted of 10 minutes of cycling, muscle stretching (2 min) and 2-3 submaximal and 1 maximal repetitions for tested velocity.

During testing the average peak torque (APT) for quadriceps and hamstrings for both limbs and conventional Hcon/Qcon ratio were recorded; APT values were calculated in relation to body mass.

The registered data homogeneity of variance of the groups was tested with Levene's test. Distribution of variables did not differ from normal distribution ($p>0.05$). Statistical analysis was based on the ANOVA/MANOVA multifactor analysis of variance. Interaction between: tested group x tested extremity x movement was estimated. In case of statistical significance the post hoc T Tukey's test was conducted. Statistical significance was accepted on the level of $p<0.05$. Statistica 5.0 software was used in the whole statistical analysis [22].

TABLE I. ANTHROPOMETRIC CHARACTERISTICS OF SUBJECTS; MEAN VALUES AND STANDARD DEVIATIONS

	Group A	Group B	Group C
Age (years)	20.30±1.32	21.3±3.90	22.85±1.98
Height (cm)	175.34±3.34	178.25±5.19	182.35±4.42
Weight (kg)	70.79±8.93	70.43±7.42	73.79±6.46

RESULTS

Table 2 presents APT values for 60°/s and 120°/s in group A for flexion and extension of the dominant and non-dominant limb. As can be seen in the table, APT values for quadriceps muscles are higher than for hamstrings group in healthy subjects.

Table 3 shows APT values (Nm/kg) in groups B and C. As can be seen in this table, values for 60°/s for extension are generally lower on the involved side, which indicates pathology of the musculotendinous system. The same tendency can be seen for higher testing velocity.

In group A results confirmed a statistically significant difference for extension for both velocities (Fig. 1). The difference can be seen

TABLE 2. AVERAGE PEAK TORQUE (APT) VALUES (Nm/kg) IN GROUP A (HEALTHY SUBJECTS) FOR BOTH ISOKINETIC VELOCITIES

		Dominant side		Non-dominant side	
Group	Movement	APT	SD	APT	SD
Testing velocity 60°/s					
A	Extension	3.78	0.41	3.76	0.55
	Flexion	2.21	0.30	2.19	0.33
Testing velocity 120°/s					
A	Extension	3.04	0.36	3.00	0.35
	Flexion	2.00	0.28	1.97	0.32

TABLE 3. AVERAGE PEAK TORQUE (APT) VALUES (Nm/kg) IN GROUPS B AND C FOR 60°/s AND 120°/s ANGULAR VELOCITIES

		Involved side		Uninvolved side	
Group	Movement	APT	SD	APT	SD
Testing velocity 60°/s					
B	Extension	3.21	0.77	3.13	0.51
	Flexion	1.97	0.35	1.99	0.31
C	Extension	3.22	0.87	3.35	0.87
	Flexion	2.32	0.57	2.33	0.51
Testing velocity 120°/s					
B	Extension	2.75	0.39	2.78	0.40
	Flexion	1.83	0.30	1.81	0.25
C	Extension	2.58	0.63	2.67	0.61
	Flexion	2.01	0.47	2.07	0.45

in both dominant and non-dominant limbs. There was no statistically significant difference between APT values in both sides (dominant and non-dominant side).

For all groups conventional Hcon/Qcon ratio was calculated (Tables 4 and 5). As seen in Table 4, Hcon/Qcon ratio values are higher in respected groups for 120°/s velocity. In group A, the value of Hcon/Qcon is 0.58 for dominant and non-dominant side and it is close to what is generally considered as the regular value for knee muscle balance.

In group B and C, the values of Hcon/Qcon ratio are lower for the involved side for both velocities, which can be explained by musculotendinous insufficiency. The graphic interpretation of the respective results is presented in Fig. 2.

As seen in Table 5, the Hcon/Qcon ratio values are highest in group C (severe injury). We can conclude that the value of this parameter reflects the degree of injury and musculotendinous insufficiency.

T Tukey's post hoc test confirmed statistically significant difference values of Hcon/Qcon ratio between groups A and C, as well as B and C for 120°/s velocity, and for the involved side for 60°/s. These results can be indicative of severity of damage to limb between groups B and C.

TABLE 4. Hcon/Qcon RATIO VALUES IN ALL GROUPS

Side	Velocity	Group A		Group B		Group C	
		Hcon/ Qcon	SD	Hcon/ Qcon	SD	Hcon/ Qcon	SD
Involved side (non-dominant)	60°/s	0.58	0.06	0.59	0.09	0.77	0.21
	120°/s	0.66	0.09	0.66	0.06	0.83	0.18
Uninvolved side (dominant)	60°/s	0.58	0.04	0.64	0.08	0.73	0.16
	120°/s	0.68	0.08	0.65	0.06	0.84	0.18

TABLE 5. MIN AND MAX VALUES OF Hcon/Qcon RATIO IN ALL GROUPS

Side	Velocity	Group A		Group B		Group C	
		Min	Max	Min	Max	Min	Max
Involved side (non-dominant)	60°/s	0.52	0.65	0.49	0.73	0.56	1.48
	120°/s	0.54	0.79	0.53	0.75	0.57	1.28
Uninvolved side (dominant)	60°/s	0.49	0.65	0.46	0.74	0.49	1.31
	120°/s	0.52	0.83	0.54	0.75	0.58	1.25

DISCUSSION

Muscle imbalance as a result of decreased strength of agonist or antagonist muscle group is most often seen as a factor increasing the risk of injury. There is a proven relationship between muscle strength deficit and increased risk of injury [8]. Comprehending the work of both synergistic and antagonistic mechanisms of knee flexors and extensors is crucial for understanding its complex functioning.

Muscle strength can be precisely measured by isokinetic devices. In this study, for the purpose of the evaluation of maximal strength, 60°/s angular velocity was selected as it is considered the closest related to maximal concentric strength of a tested subject [26].

Isokinetic testing has one important advantage: it is safe for the tested person, because during movement the dynamometer's arm adjusts to the moment of force generated by the patient. Therefore, during ROM the patient never meets resistance that he or she is not able to overcome (as it may take place with isotonic exercise). At the same time, during the isokinetic tests, the patient generates maximal force. This helps to develop the highest values of muscle strength. This relationship of strength to ROM value can be very helpful for clinical diagnosis [23]. In this way we can verify an athlete's status and readiness for physical performance. On the basis of the results of isokinetic testing we can design an individualized strength training

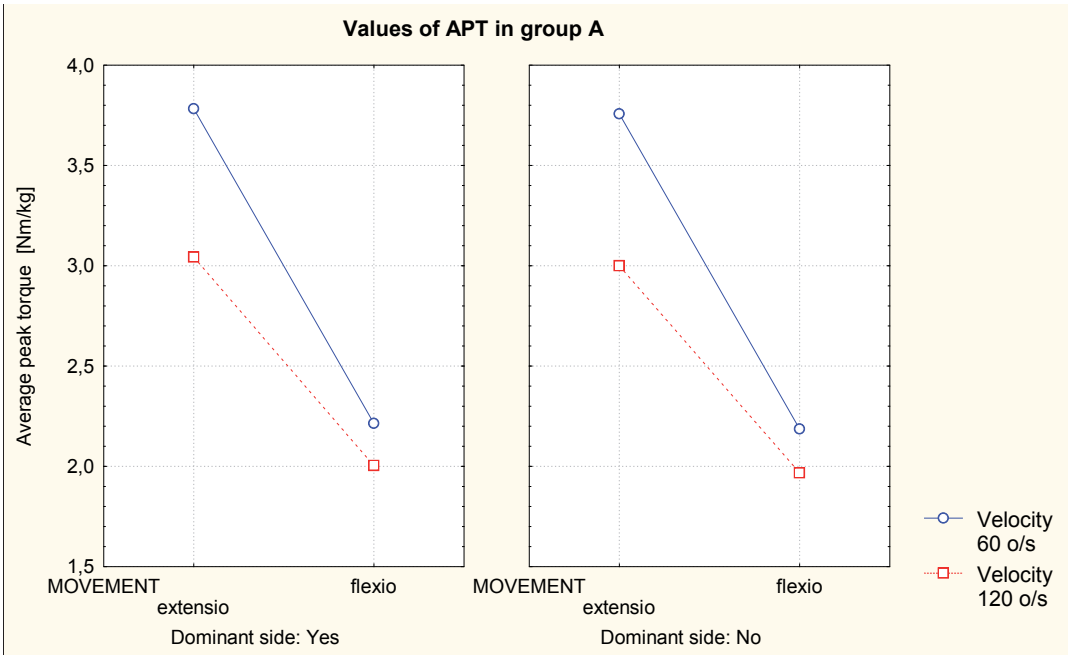

FIG. 1. AVERAGE PEAK TORQUE (APT) VALUES IN GROUP A

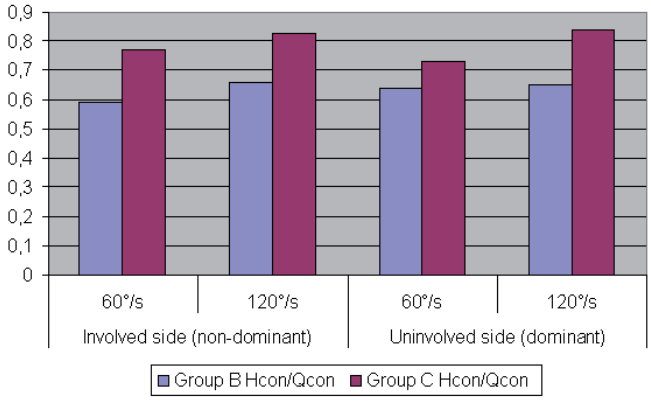

FIG. 2. GRAPHIC REPRESENTATION OF Hcon/Qcon RATIO FOR GROUPS WITH INJURED KNEE

program to cater to the athlete's needs and to reduce risk of injury. In an injury prevention program it is important to calculate the ipsilateral conventional Hcon/Qcon ratio. It is widely used in the search of proper relationship between strength of agonist and antagonist knee muscle groups in various biomechanical conditions and in force-velocity relations [18,28]. It is also used by some some authors to evaluate functional abilities of knee joint [11]. Hcon/Qcon value describes predisposition to knee injuries [6,7]. According to some authors, Hcon/Qcon ratio value lower than 0.6 with concomitant contralateral asymmetry between hamstrings strength (higher than 5%), should exclude the subject from active participation in sports and direct him/her to a rehabilitation process [6]. Very often, after a knee injury, the correct value of Hcon/Qcon is a goal to be achieved to reestablish proper muscle balance and stability of knee joint [3]. According to various authors, conventional Hcon/Qcon ratio value for 60°/s velocity should be equal to 0.63–0.66 [6,24]. Values calculated in our study are similar to those presented in bibliography. Among athletes without any injuries to the knee joint, values for dominant and non-dominant side ranged from 0.49 to 0.65 and from 0.52 to 0.65, respectively.It can be seen that values achieved in our study are slightly lower for group A than in cited research. This difference can be caused by the specificity of sport training which is focused on strength development. This observation has been confirmed by other studies [25]. Also, statistically significant difference between Hcon/Qcon ratio values between group A and C can be seen, as well as between B and C for 120°/s velocity. This difference can be explained by the lower value of quadriceps muscle strength in knee injured group due to muscle atrophy of the fast twitch fibers [20].

However, the use of conventional Hcon/Qcon ratio for the calculation of injury risk has some restrictions. Conventional Hcon/Qcon ratio is a calculation that is based on concentric work of agonist and antagonist muscle groups. It is not a physiologic act that takes place in sport-related activity. Concentric work of agonist group (knee extensors) is accompanied by simultaneous eccentric work of antagonist muscles (knee flexors). Hence, it is imperative to evaluate and maintain the interdependence of muscle groups in these respective types of muscle activities.

Muscle dysbalance around knee joint can cause various injuries, especially straining of the hamstrings group. The question that arises, i.e. will the correction of the antagonist muscle imbalance reduce the risk of injury, so far has not been answered completely. Conventional Hcon/Qcon ratio value of 0.6 is widely used as normative, but further analysis and search for injury causes have to be undertaken, for it seems that research available today is not supportive enough to draw an ultimate conclusion about this value. Still, there is a significant quantity of research, acquired during isokinetic testing, which supports this value as an objective parameter that can be used for calculation of the risk of injury. Perhaps further analysis of other parameters describing dynamic relationship between knee flexors and extensors (including eccentric muscle contraction, as proposed by Aagaard – dynamic or functional ratio [1]), including the analysis of the strength-velocity relationship in specific ROM, will be even more effective in successful sports injury prevention.

CONCLUSIONS

1.Isokinetic testing enables precise muscle strength assessment in athletes. The result of such testing, calculated conventional Hcon/Qcon ratio, describes muscle balance and can be used in injury prevention.

2.Different values achieved in group A (healthy subjects) and group C (knee injured subjects) reflect severity of injury and health status at the time of testing.

3.There is a need to further investigate the conventional ratio of muscle balance, in relation to different degrees of intra-articular and out-articular injuries in different kinds of athletes, in order to effectively limit and minimize the causes of injuries.

REFERENCES

1.Aagaard P., Simonsen E., Magnusson S., Larsson B., Dyhre-Poulsen P. A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am. J. Sports Med. 1998;26:231-237.
2. Aagaard P., Simonsen E., Trolle M., Bangsbo J., Klausen K. Isokinetic hamstring/quadriceps strength ratio: influence from joint angular velocity, gravity correction and contraction mode. Acta Physiol. Scand. 1995;154:421-427.
3. Bonci C. Assessment and evaluation of predisposing factors to anterior cruciate ligament injury. J. Athlete Training 1999;34:155-164.
4. Croisier J., Maerens de Noordhout B., Maquet D., Camus G., Hac S., Feron F., De Lamotte O., Crielaard J. Isokinetic evaluation of hip strength muscle groups in unilateral lower limp amputees. Isokinet. Exerc. Sci. 2001;9:163-169.
5. Croisier J.-L., Crielaard J-M. Hamstring muscle tear with recurrent complaints: an isokinetic profile. Isokinet. Exerc.Sci. 2000;8:175-180.
6. Dauty M., Potiron-Josse M., Rochcongar P. Identification of previous hamstring muscle injury by isokinetic concentric and eccentric torque measurement in elite soccer player. Isokinet. Exerc. Sci. 2003;11:139-144.
7. Devan M., Pescatello L., Faghri P., Anderson J. A prospective study overuse knee injuries among female athletes with muscle imbalances and structural

abnormalities. J. Athlete Training 2004;39:263-267.
8. Ekstrand J., Gillquist J. Soccer injuries and their mechanism: a prospective study. Med. Sci. Sports Exerc. 1983;15:267-270.
9. Harter R., Osternig L., Standifer L. Isokinetic evaluation of quadriceps and hamstring symmetry following anterior cruciate ligament reconstruction. Arch. Phys. Med. Rehabil. 1990;71:465-468.
10. Heiser T., Weber J., Sullivan G., Clare G., Jacobs R. Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. Am. J. Sports Med. 1984;12:368-370.
11. Hewett T. Associated with knee injuries in female athletes. Sports Med. 2000;29:313-327.
12. Hiemstra L., Webber S., MacDonald P., Kriellaars D. Hamstring and quadriceps strength balance in normal and hamstring anterior cruciate ligament-reconstructed subjects. Clin. J. Sport Med. 2004;14:274-280.
13. Hole C., Smith G., Hammond J., Kumar A., Saxton J., Cochrane T. Dynamic control and conventional strength ratios of the quadriceps and hamstring in subjects with anterior cruciate ligament deficiency. Ergonomics 2000;43:1603-1609.
14. Jones B., Knapik J. Physical training and exercise-related injuries. Sports Med. 1999;27:111-125.
15. Kellis S., Gerodimos V., Kelis E., Manou V. Bilateral isokinetic concentric and eccentric strength profiles of the knee extensors and flexor in young soccer players. Isokinet. Exerc. Sci. 2001;9:31-39.
16. Lee H., Holcomb W., Rubley M., Mercer J., Morcos A. Hamstring to quadriceps strength ratios: an analysis and strength training study. J. Athlete Training 2004;39:29.
17. Li R., Maffulli N., Hsu Y., Chan K. Isokinetic strength of the quadriceps and hamstring and functional ability of anterior cruciate deficient knees in recreational athletes. Br. J. Sports Med. 1996;30:161-164.
18. MacLean C., Taunton J., Clement D., Regan W. Eccentric and concentric isokinetic moment characteristics in the quadriceps and hamstrings of the chronic isolated posterior cruciate ligament injured knee. Br. J. Sports Med. 1999;33:405-408.
19. Magalhaes J., Oliviera J., Ascensao A., Soraes J. Concentric quadriceps and hamstring isokinetic strength in volleyball and soccer players. J. Sports Med. Phys. Fitness 2004;44:119-125.
20. Rosene J., Fogarty T., Mahaffey B. Isokinetic hamstring quadriceps ratios in intercollegiate athletes. J .Athlete Training 2001;36:378-383.
21. Siatras T., Mameletzi D., Kellis S. Knee flexor: extensor isokinetic ratios in young male gymnasts and swimmers. Pediatr. Exerc. Sci. 2004;16:37-43.
22. Statistica for Windows, Release 5.0 A, Copyright © Stat-Soft, 1997.
23. Tae Sik Yoon, Dong Sik Park, Seoung Woong Kand Sae-il Chun, Jung Soon Shin Isometric and isokinetic torques curves at the knee joint. Yonsei Med. J. 1991;32(1):33-42.
24. Tourny-Chollet C., Leroy D. Conventional vs. dynamic hamstring-quadriceps strength ratios: a comparison between players and sedentary subject. Isokinet. Exerc. Sci. 2002;10:183-192.
25. Tourny-Chollet C., Leroy D., Delarue Y., Beuret-Blanquart F. Isokinetic-based comparison of hamstring-quadriceps ratio between soccer players and sedentary subjects. Isokinet. Exerc. Sci. 2003;11:85-86.
26. Tourny-Chollet C., Leroy D., Leger H., Beuret-Blanquart F. Isokinetic knee muscle strength of soccer players according to their position. Isokinet. Exerc. Sci. 2000;8:187-193.
27. Wilk K., Romaniello W., Soscia S., Arrigo C., Andrews J. The relationship between subjective knee scores, isokinetic testing and functional testing in the ACL-reconstructed knee. J. Orthop. Sports Phys. Ther. 1994;20:60-73.
28. Wilkerson G., Colston M., Short N., Neal K., Hoewischer P., Pixley J. Neuromuscular changes in female collegiate athletes resulting from a plyometric jump training program. J. Athlete Training 2004;39:17-23.
29. Worrell T., Perrin D., Denegar C. The influence of hip position on quadriceps and hamstring peak torque and reciprocal muscle group ratio values. J. Orthop. Sports Phys. Ther. 1989;11:104-107.