Rheumatol Int
DOI 10.1007/s00296-007-0493-4

ORIGINAL ARTICLE

Isokinetic evaluation of knee extensor/flexor muscle strength in patients with hypermobility syndrome

Nilay Sahin · Akin Baskent · Hatice Ugurlu · Ender Berker

Received: 12 June 2007 / Accepted: 10 November 2007

Abstract Benign joint hypermobility syndrome (BJHS) is a syndrome with musculoskeletal pain originating from the increased laxity of the joints and the ligaments. The study was to compare the isokinetic strength of knee extensor/flexor muscles of BJHS patients with healthy controls. Forty patients diagnosed as having BJHS with Brighton criteria and 45 years of age, height and weight-matched healthy controls were recruited for the study. Isokinetic testing was performed with isokinetic dynamometry of Biodex System 3Pro and measurements were recorded at knee extension/flexion pattern concentrically at 60, 180, and 240°/s angular velocities. The study group was also evaluated for functional impairment and pain by HAQ and VAS respectively. Knee extensor muscle strength was significantly lower in the patient group compared with the controls. It was hypothesized that the muscle weakness in the study group was related to lengthening of the quadriceps muscle and pain-related inactivity as well as joint instability and proprioception defect.

Keywords Benign joint hypermobility syndrome · Isokinetic · Evaluation · Knee

N. Sahin (✉) · H. Ugurlu
Physical Medicine and Rehabilitation Department, Meram Faculty of Medicine, Selcuk University, Meram, Konya, Turkey
e-mail: nilaysahin@gmail.com

H. Ugurlu
e-mail: haticeugurlu@gmail.com

A. Baskent
Physical Medicine and Rehabilitation Department, Istanbul Faculty of Medicine, Istanbul University, Capa, Istanbul, Turkey
e-mail: akinbaskent@gmail.com

E. Berker
Physical Medicine and Rehabilitation Department, Vehbi Koc Foundation, American Hospital, Nisantasi, Istanbul, Turkey
e-mail: meberker@ttnet.com

Introduction

Benign joint hypermobility syndrome (BJHS) is a rheumatological, genetically transmitted syndrome related to variations and mutations of the genes coding collagen, elastin, fibrillin and tenascin and has a clinical picture of musculoskeletal pain in various areas of the body [1–3]. The syndrome is termed as benign since it has no life-threatening complication. The prevalence is 0.6–31% in adults and is five times common in females [4]. There are no laboratory or radiologic diagnostic criteria and present diagnosis is based on generalized laxity and specific joint involvement. Carter-Wilkinson, Beighton, Bulbena and Rotes have worked to identify the diagnostic criteria and Brighton's criteria have been accepted presently [5, 6] (Table 1). The basic pathology in this syndrome is the involvement of collagen tissue with a decrease in the width and increase in the disorganized fiber ratio and this pathologic structure leads to decreases in the tonus of body elastic tissue with an increased tendency to traumatic lesions [3].

The loss of soft-tissue strength is accompanied by unstable joints with laxity, loss of proprioception, tendency for traumatic injuries and pain-related inactivity [7].

Recordings of isokinetic muscle performance in increasing angular velocities may give a clue for muscle strength loss [8]. Isokinetic dynamometer gives an objective value of muscle strength and muscle contraction force by allowing maximal muscle contraction with predetermined

Table 1 Characteristics of patients with benign joint hypermobility syndrome (BJHS) and control group (CG)

	CG (*n*: 45)	BJHS (*n*: 40)
Age/mean	26.73 (18–50)	27.87 (19–49)
Sex	25F:10M	32F:8M
Height	167.84	166.00
Weight	66.80	63.25
VAS on motion	0	2.83 ± 2.29
VAS at rest	0	1.10 ± 1.69
HAQ		
Dressing		0.23 ± 0.48
Arising		0.33 ± 0.52
Eating		0.33 ± 0.68
Walking		0.33 ± 0.54
Hygiene		0 ± 0
Reach		0.43 ± 0.71
Grip		0.48 ± 0.78
Usual activities		0.57 ± 0.84

F female, *M* male

angular velocities at all angles [9, 10]. This procedure has been used in rheumatological diseases like rheumatoid arthritis, osteoarthritis and fibromyalgia syndrome and standard methods have been produced to evaluate the therapeutic outcomes [9, 11–17].

The primary aim of the study is to measure the isokinetic muscle strength (peak torque) of knee extensor/flexor muscle of BJHS patients and to compare the scores with healthy controls and the secondary aim is to evaluate the relation between the scores and functional status and pain intensity in these patients.

Materials and methods

Forty cases with an age range of 19–49 diagnosed as having BJHS at the Out-patient Department of Physical Medicine and Rehabilitation Clinic of Istanbul Medical Faculty and 45 healthy volunteers with an age range of 18–50 were recruited for the study. The diagnostic criteria according to the Brighton diagnostic 1998 criteria were Beighton scores of 4/9 or above plus one major or two minor symptoms with no lumbar pain or hip pain, no severe knee pain, osteoarthritic symptoms or ligament injury determined by physical examination, and X-rays. The age and sex-matched were recruited from the healthy volunteers of the hospital staff. Cases with serious knee trauma, hip pain, knee and hip osteoarthritis demonstrated by X-rays, other comorbidities and ligament injury were excluded from the study.

Evaluation parameters

Isokinetic muscle strength of knee extensor/flexor muscles in both the groups was measured by Biodex System 3Pro Multijoint System Isokinetic Dynamometer (Biodex Medical Inc, Shirley/NY, USA). Visual analog scale (VAS) and health assessment questionnaire (HAQ) were used to determine the pain intensity and functional status in BJHS patients [18–21].

Muscle testing

Biodex System 3Pro Multijoint System was used for isokinetic testing in both the groups. Tests were applied according to the standardization of isometric scoring by Wilk et al. [15, 16]. Warm-up period of 10 min at 60-rpm velocity was applied. The dynomometer arm was positioned parallel to the patient's leg with distally fixed peds and the distal resistance ped was stabilized. The patient's position and the dynomometer chair were also stabilized by the bands across the thorax, hip and calf regions. All the cases were formerly informed about the testing procedure to increase the compliance. Since tests at low-angular velocities report more accurate recordings of endurance and functional status of the muscles [8, 22, 23], 60, 180 and 240°/s angular velocities of slow, medium and high speed were used for knee extension/flexion patterns [23–25]. Dominant side was first measured followed by the contralateral side. Extension/flexion movement of four repetitions for the first two initial velocities and 20 repetitions for the last angular velocity was applied. Peak torque (PT), % of peak torque/body weight (PT/BW), maximal repetition total work (MRTW), % work/body weight (W/BW) and % of agonist/antagonist ratio (ag/an) isokinetic scores were noted for each velocity. Muscular strain was prevented by 60 s resting periods between each angular velocity and verbal input was applied to motivate the cases for maximal effort in the testing room with a stabile temperature [26]. PT is the highest torque value for a predetermined angular velocity and it is the most utilized score for research [23]. Age, sex, dominant extremity, body mass index (BMI), fat ratio and waist circumference may all effect PT values [27]. PT/BW ratio is used to personalize, standardize and interpret isokinetic scores [28]. MRTW is a value that shows the relation between flexion and extension [24, 29, 30]. W/BW could be a better representation of functional ability (over PT) because the muscle must maintain force throughout the range of motion (ROM) as opposed to force at one instant [30]. Ag/an notes the balance between knee extensor/flexor muscles and the integrity of the ligaments [30–33].

Statistical analysis

An Independent samples *t*-test was used to compare the patient and control groups and a paired samples *t*-test was used to compare the left and right extremities of the patient group. $P < 0.05$ values were accepted as statistically significant.

Results

The mean age of 32 females and 8 males with BJHS was 27.87 ± 8.12 and all the cases had Beighton scores of 4/9 or higher. The mean age of 25 female and 20 male controls was 26.73 ± 9.22. Table 1 shows the demographic features of both the groups and VAS and HAQ values. There was no statistical significant difference between the groups in relation to sex, height and weight ($P > 0.05$). VAS values of the patient group were below 5 points. HAQ scores of the patient group were not at high level. The control group had no knee hyperextension whereas 80% of the patient group had knee hyperextension. Goniometric measures of knee flexion were 130° for both the groups with no statistical significance ($P > 0.05$). The dominant side was the right side for both the groups. PT of knee extensor/flexor muscle groups in BJHS patients was significantly lower compared to the controls. The significance at 60°/s right and left extension were $P = 0.005$ and $P \leq 0.01$, respectively and left flexion was $P = 0.04$. At 180°/s, the significance was right extension ($P = 0.014$) and left extension ($P = 0.02$) and at 240°/s, right and left extension were $P = 0.013$ and $P = 0.045$, respectively. There was no statistical difference between the patient and control groups in flexion at 180 and 240°/s angular velocities (Tables 2, 3). In PT/WB scores, the patient group had significant lower scores compared to the control group at 60°/s angular velocity for right ($P = 0.006$) and left ($P = 0.028$) extension, at 180°/s angular velocity for right ($P = 0.018$) and left ($P = 0.027$) extension and at 240°/s, only right extension ($P = 0.025$) showed significant difference. There was no significant difference in the flexion scores of the right and left knees at 60, 180 and 240°/s angular velocities between the study and control groups ($P > 0.05$) (Tables 2, 3). MRTW scores showed that BJHS patients had statistically lower scores ($P < 0.05$) at 60, 180 and 240°/s angular velocities in right and left extension and only at 60°/s angular velocity for left side flexion. There was no significant difference at 60°/s for right flexion and at 180°/s and 240°/s for right and left flexion ($P > 0.005$) (Tables 2, 3). W/WB scores for the study group were significantly lower compared to controls at 60, 180 and 240°/s in extension ($P > 0.05$) (Tables 2, 3). The study group had significant higher scores of ag/an at left 180 and 240°/s compared to the controls ($P < 0.05$), whereas there was no statistical difference at 60°/s angular velocity on the right and left and at 180 and 240°/s velocities on the right side ($P > 0.05$). The study group had higher scores of ag/an and this may be the result of decreased extension in contrast to increased flexion. Ag/an scores showed difference between the dominant and non-dominant sides in the study group, which was statistically significant at 60°/s on the right ($P \leq 0.001$) (Table 4). Most of the cases in the study group had lower PT. In isokinetic testing, 60°/s velocity is regarded as the best marker for strength and our results show significant lower scores for both extensor and flexor muscle groups in the study group. In higher velocities of 180 and 240°/s, the scores for the extensor group were also lower in the patients compared to the controls, whereas there was no statistical difference between the groups for flexor muscles. The extensor muscle groups of the patients also showed significant lower scores of PT/BW values that normalize data with no difference in flexor muscle groups when compared with the controls.

There is no significant correlation between PT and HAQ and VAS in patient group.

Discussion

Isokinetic dynamometer testing is used for objective recording of muscle performance, evaluation of rehabilitation out-comes in musculoskeletal injury, loss of muscle strength as well as for recording the relation between agonist and antagonist muscle groups [24]. Isokinetic measurments are recorded in low, medium and high velocities since duration and velocity are important parameters in skeletal muscle training [24, 34]. There is no standardized isokinetic measurement in BJHS, so we have used four repetitions at 60 and 180°/s and 20 repetetions at 240°/s angular velocities in our study. Isokinetic measurments in chronic pain states like osteoarthritis, rheumatoid arthritis, fibromyalgia syndrome and chronic low back pain have utilized similar angular velocities with multiple repetetions [9, 14, 23–25, 29]. The most valid parameter in isokinetic measurements is PT which may be affected by BMI and PT/BW values are important in this issue as well as MRTW scores which reflect the balance between flexor and extensor muscle groups [23, 24, 27–30]. The above parameters showed significant lower scores of knee extensor muscles on both the sides in our patient group as compared to the controls, which was interpreted as decreased extensor muscle strength in the BJHS patients. PT values of knee flexors at lower angular velocities were also significantly lower in patient group. The main factor for decreased muscle strength is pain related inactivity and laxity of the ligaments with instability of the joints [5]. Various studies have demonstrated a strong relation between ligament laxity, muscle

Table 2 Means of parameters evaluated by the isokinetic test

Group			BJHS				CG	
M	Extensors		Flexors		Extensors		Flexors	
S	R	L	R	L	R	L	R	L
PT								
60°/s	121.03 ± 31.42	119.30 ± 34.00	59.17 ± 19.72	54.12 ± 20.02	148.57 ± 52.49	144.94 ± 52.60	69.93 ± 29.01	63.96 ± 23.02
180°/s	86.11 ± 25.25	86.09 ± 24.83	52.16 ± 18.83	56.38 ± 20.57	103.73 ± 37.51	102.68 ± 37.70	58.29 ± 21.73	57.26 ± 21.78
240°/s	76.46 ± 20.54	79.06 ± 22.87	58.77 ± 20.94	64.91 ± 23.39	91.99 ± 33.66	91.79 ± 32.59	63.06 ± 20.59	64.36 ± 23.53
PT/BW								
60°/s	193.27 ± 38.40	190.11 ± 40.04	94.15 ± 24.31	86.11 ± 26.17	222.48 ± 55.05	214.78 ± 58.53	103.05 ± 30.41	95.19 ± 25.02
180°/s	135.36 ± 30.09	135.19 ± 29.04	82.68 ± 24.80	87.62 ± 25.62	154.33 ± 40.60	153.21 ± 42.76	86.70 ± 24.44	85.84 ± 26.66
240°/s	121.52 ± 22.48	125.59 ± 26.75	92.67 ± 23.47	102.80 ± 28.44	136.94 ± 37.10	136.86 ± 36.21	94.68 ± 24.90	96.81 ± 30.22
MRTW								
60°/s	130.58 ± 34.67	124.68 ± 34.26	68.52 ± 24.81	61.52 ± 23.18	160.90 ± 52.98	153.08 ± 51.12	80.45 ± 34.12	72.82 ± 27.79
180°/s	97.98 ± 28.58	97.13 ± 27.03	50.63 ± 20.95	48.21 ± 18.28	119.94 ± 42.54	117.68 ± 39.96	60.30 ± 26.89	53.26 ± 21.60
240°s	84.32 ± 22.15	85.15 ± 24.34	45.15 ± 18.07	42.11 ± 17.42	102.78 ± 36.99	102.06 ± 34.80	50.39 ± 21.98	45.39 ± 17.74
W/BW								
60°/s	208.63 ± 43.09	199.04 ± 41.65	108.86 ± 30.52	99.16 ± 30.27	240.54 ± 57.45	229.16 ± 56.60	118.80 ± 37.44	108.62 ± 32.51
180°/s	155.70 ± 33.36	154.12 ± 29.96	80.07 ± 25.85	77.19 ± 21.70	178.34 ± 45.39	176.06 ± 45.89	88.90 ± 30.68	79.45 ± 26.59
240°/s	133.30 ± 24.56	135.19 ± 28.08	70.48 ± 22.14	65.96 ± 23.37	152.94 ± 39.38	152.66 ± 39.46	74.65 ± 24.85	67.99 ± 22.70

CG Control group, *M* movement, *S* side, *R* right, *L* left, *PT* peak torque (Nm), *PT/BW* peak torque/body weight (%), *MRTW* maximal repetition total work (Joule-J), *W/BW* work/body weight (%)

Table 3 *P* values of isokinetic testing in BJHS

	(L) BJHS-CG extension		(R) BJHS-CG extension		(L) BJHS-CG flexion		(R) BJHS-CG flexion	
	t	*P*	*t*	*P*	*t*	*P*	*t*	*P*
PT								
60°/s	−2.631	0.010	−1.974	0.052	−2.089	0.040	−2.889	0.005
180°/s	−2.364	0.020	−1.381	0.171	−0.192	0.848	−2.506	0.014
240°/s	−2.060	0.043	−0.951	0.344	0.108	0.914	−2.528	0.013
PT/BW								
60°/s	−2.240	0.028	−1.478	0.143	−1.635	0.106	−2.802	0.006
180°/s	−2.244	0.027	−0.751	0.455	0.313	0.755	−2.421	0.018
240°/s	−1.615	0.110	−0.382	0.703	0.936	0.352	−2.281	0.025
MRTW								
60°/s	−2.969	0.004	−1.824	0.072	−2.021	0.047	−3.079	0.003
180°/s	−2.744	0.007	−1.833	0.070	−1.155	0.252	−2.757	0.007
240°s	−2.564	0.012	−1.192	0.237	−0.859	0.393	−2.747	0.007
W/BW								
60°/s	−2.764	0.007	−1.127	0.263	−1.383	0.170	−2.867	0.005
180°/s	−2.574	0.012	−1.426	0.158	−0.427	0.671	−2.592	0.011
240°/s	−2.325	0.023	0.673	0.503	−0.406	0.685	−2.719	0.008

strength and functional status, as well as proprioceptive dysfunction and muscle strength loss in BJHS patients and these patients often suffer ligament injury due to trauma and laxity [11, 35–41]. Shirakura et al. [42] have reported a significant difference, in knee PT values between healthy people and those with ligament injury. In BJHS patients early degenerative changes in the knee joint may develop due to weakness of the ligaments and supporting muscle groups [37, 43]. van der Esch et al. [11] in their study of knee osteoarthritis have reported lower muscle strength and

Table 4 Ratio of agonist/antagonist parameters evaluated by the isokinetic test

Group	BJHS			CG			L BJHS-CG	R BJHS-CG
AV	R	L	P	R	L	*P*	*P*	*P*
60	48.52 ± 6.73	44.84 ± 7.53	0.001	46.58 ± 8.93	44.69 ± 7.62	0.086	0.267	0.929
180	60.50 ± 11.73	65.66 ± 14.75	0.009	57.25 ± 13.44	57.15 ± 13.73	0.956	0.242	0.007
240	76.59 ± 14.96	81.48 ± 13.87	0.028	71.03 ± 17.61	71.91 ± 18.95	0.736	0.123	0.001

R Right, *L* left, *AV* angular velocity (°/s)

lower functional scores in patients with laxity compares to those without laxity, whereas Goradia et al. [44] have found no relation between knee muscle weakness and articular cartilage or meniscal pathology. PT values are significantly lower in chronic pain states as mentioned above and fatigue with fibromyalgia, which usually accompanies BJHS may lead to deconditioning that affects muscle strength and performance [13, 14, 45, 46]. The above data may clarify our findings of muscle weakness in our BJHS patient group. MRTW scores, which reflect the balance between extensor and flexor muscle groups, were significantly lower in our study group and this was interpreted as lower flexor and even lower extensor strength in the BJHS patient [9]. Isokinetic measurement studies at various velocities of knee extensors and flexors of both dominant and non-dominant sides in healthy normals have been reported as unchanged [47, 48]. Since ROM of the knee joint reflects the function of activation of both flexor and extensors, a normal knee function requires the balance between quadriceps and hamstring muscles, which also decrease the possibility of knee injuries [39, 49]. Grace et al. [50] in their study, investigating hamstring/quadriceps ratio in their cases with former knee injury have reported a 10% difference and this difference may also be an effective factor in ligament and muscle injury as well as laxity in BJHS cases [35, 39]. Extensor muscle strength should be increased in this group to obtain optimal muscle balance and exercise should be targeted to that end point and this was demonstrated by Barton and Bird [51] applying stabilization exercises which positively affected muscle strength, increased functional capacity and decreased pain. Pain, which is usually localized to the knee joint, is the major complaint of BJHS cases and is caused by tissue or overuse and chronicity usually develops by neuroplasticity at central nervous system [2, 3]. Trauma whether microrepetitive or macrotrauma is the major predisposing factor, which is usually due to the changes in connective tissue [45].

In our study we have objectively demonstrated the weakness of the knee extensor muscles in our BJHS cases. We have also found decreased strength in the flexor muscle groups and we have concluded that exercises targeted at increasing both the strength and the balance of extensor and flexor muscle groups should be applied in these cases and isokinetic measurements should be performed to evaluate the out-comes.

References

1. Grahame R (2000) Hypermobility. Int J Clin Pract 54:314–315
2. Everman DB, Robin NH (1998) Hypermobility Syndrome. Pediatr Rev 19:111–117
3. Russek LN (1999) Hypermobility syndrome. Phys Ther 79:591–599
4. Silverman S, Constine L, Harvey W (1975) Survey of joint mobility and in vivo skin elasticity in London schoolchildren. Ann Rheum Dis 34:177–180
5. Grahame R (2003) Hypermobility and hypermobility syndrome. In: Keer R, Grahame R (eds) Hypermobility syndrome. Elsevier, London, pp 1–12
6. Grahame R, Brid H, Child A (2000) The revised (Brighton 1998) criteria for the diagnosis of benign joint hypermobility syndrome. J Rheumatol 27:1777–1779
7. Maillard S, Murray KJ (2003) Hypermobility Syndrome in Children. In: Keer R, Grahame R (eds) Hypermobility syndrome. Elsevier, London, pp 41–43
8. Kannus P, Beynnon B (1993) Peak torque occurrence in the range of motion during isokinetic extension and flexion of the knee. Int J Sports Med 14:422–426
9. Meireles SM, Oliveira LM, Andrade MS, Silva AC, Natour J (2002) Isokinetic evaluation of the knee in patients with rheumatoid arthritis. Joint Bone Spine 69:566–573
10. Baltzopoulos V, Brodie DA (1989) Isokinetic dynamometry. Applications and limitations. Sports Med 8:101–116
11. van der Esch M, Steultjens M, Knol DL, Dinant H, Dekker J (2006) Joint laxity and the relationship between muscle strength and functional ability in patients with osteoarthritis of the knee. Arthritis Rheum 55:953–959
12. Hsieh LF, Guu CS, Liou HJ, Kung HC (1992) Isokinetic and isometric testing of knee musculature in young female patients with patellofemoral pain syndrome. J Formos Med Assoc 91:199–205
13. Borman P, Celiker R, Hascelik Z (1999) Muscle performance in fibromyalgia syndrome. Rheumatol Int 19:27–30
14. Maqeut D, Croisier JL, Renard C, Crielaard JM (2002) Muscle performance in patients with fibromyalgia. Joint Bone Spine 69:293–299
15. Perrin DH (1993) Isokinetic exercise and assessment. Human Kinetics Publishers, Champaign (IL), pp 6–37
16. Wilk KE (1995) Isokinetic testing and exercise for the knee. In: Mangine RE (ed) Physical therapy of the knee. Churchill Livingstone, New York, pp 263–288
17. Baltzopoulos V (1995) Muscular and tibiofemoral joint forces during isokinetic concentric knee extension. Clin Biomech 10:208–214

18. Bowsher D (1998) Acute and chronic pain and assessment. In: Wells PE, Frampton V, Bowsher D (eds) Pain management and physical therapy. Appletion and Lange, Norwalk, pp 8–11
19. Frank JM, Moll MH, Hort JF (1982) A comparison of three ways of measuring of pain. Rheum Rehab 21:211–217
20. Fries JF, Spitz P, Kraines R (1980) Measurment of patient outcome in arthritis. Arthritis Rheum 23:137–145
21. Kucukdeveci A, Sahin H, Ataman S (2004) Issues ın cross-cultural validity: exampla from the adaptation, reliability, and validity testing of a Turkish version of the Stanford health assessment questionnaire. Arthritis Rheum 51:14–19
22. Hall C, Brody LT (1999) Impairment of muscle performance. In: Hall CM, Brody LT (eds) Therapeutic exercise moving toward function. Williams and Wilkins, Philadelphia, pp 59–60
23. Kannus P (1994) Isokinetic evaluation of muscular performance: implications for muscle testing and rehabilitation. Int J Sports Med 15:11–18
24. Siqueira CM, Pelegrini FR, Fontana MF, Greve JM (2002) Isokinetic dynamometry of knee flexors and extensors: comparative study among non-athletes, jumper athletes and runner athletes. Rev Hosp Clin Fac Med Sao Paulo 57:19–24
25. Iossifidou AN, Baltzopoulos V (2000) Peak power assessment in isokinetic dynamometry. Eur J Appl Physiol 82:158–160
26. Osternig LR (1986) Isokinetic dynamometry: implications for muscle testing and rehabilitation. Exerc Sport Sci Rev 14:45–80
27. Gross MT, McGrain P, Demilio N, Plyler L (1989) Relationship between multiple predictor variables and normal knee torque production. Phys Ther 69:54–62
28. Borges O (1989) Isometric and isokinetic knee extension and flexion torque in men and women aged 20–70. Scand J Rehabil Med 21:45–53
29. Pincivero DM, Lephart SM, Karunakara RG (1997) Relation between open and closed kinematic chain assessment of knee strength and functional performance. Clin J Sport Med 7:11–16
30. Jacoby SM (2001) Isokinetics in rehabilitation. In: Prentice WE, Voigth ML (eds) Techniques in musculoskeletal rehabilitation. McGraw-Hill Medical Publishing Division, New York, pp 154–160
31. Fossier E, Christel P, Djian P, Darman Z, Witvoet J (1993) Principles and value of isokinetic evaluation in ruptures of the anterior cruciate ligament. Rev Chir Orthop Reparatrice Appar Mot 79:615–624
32. Bohannon RW, Gibson DF, Larkin P (1986) Effect of resisted knee flexion on knee extension torque. Phys Ther 66:1239–1241
33. Aagaard P, Simonsen EB, Magnusson SP, Larsson B, Dyhre-Poulsen P (1998) A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am J Sports Med 26:231–237
34. Lesmes GR, Costill DL, Coyle EF, Fink WJ (1978) Muscle strength and power changes during maximal isokinetic training. Med Sci Sports 10:266–269
35. Soderman K, Alfredson H, Pietila T, Werner S (2001) Risk factors for leg injuries in female soccer players: a prospective investigation during one out-door season. Knee Surg Sports Traumatol Arthrosc 9:313–321
36. Roberts D, Ageberg E, Andersson G, Friden T (2007) Clinical measurments of proprioception, muscle strength and laxity in relation to function in the ACL-injured knee. Knee Surg Sports Traumatol Arthrosc 15:9–16
37. Ferrell WR, Tennant N, Sturrock RD, Ashton L, Creed G, Brydson G, Rafferty D (2004) Amelioration of symptoms by enhancement of proprioception in patients with joint hypermobility syndrome. Arthritis Rheum 50:3323–3328
38. Hall GM, Ferrel WR, Sturrock RD (1995) The effect of the hypermobility syndrome on knee joint proprioception. Br J Rheumatol 34:121–125
39. Bowerman SJ, Smith DR, Carlson M, King GA (2006) A comprasion of factors influencing ACL injury in male and female athletes and non-athletes. Phys Ther Sport 7:144–152
40. Wilkerson GB, Pinerola JJ, Caturano RW (1997) Invertor vs. evertor peak torque and power deficiencies associated with lateral ankle ligament injury. J Orthop Sports Phys Ther 26:78–86
41. Kupper JC, Loitz-Ramage B, Corr DT, Hart DA, Ronsky JL (2007) Measuring knee joint laxity: A review of applicable models and the need for new approaches to minimize variability. Clin Biomech (Bristol, Avon) 22:1–13
42. Shirakura K, Kato K, Udagawa E (1992) Characteristics of the isokinetic performance of patients with injured cruciate ligaments. Am J Sports Med 20:754–760
43. Keays SL, Bullock-Saxton JE, Newcombe P, Keays AC (2003) The relationship between knee strenght and functional stability before and after anterior cruciate ligament reconstruction. J Orthop Res 21:231–237
44. Goradia VK, Grana WA, Pearson SE (2006) Factors associated with decreased muscle strength after anterior cruciate ligament reconstruction with hamstring tendon grafts. Arthroscopy 22:80
45. Hakim A, Graham R (2003) Joint Hypermobility (review). Best Pract Res Clin Rheumatol 17:989–1004
46. Nijs J, Meeus M, De Meirleir K (2006) Chronic musculoskeletal pain in chronic fatigue syndrome: recent developments and therapeutic implications. Man Ther 11:187–191
47. Afzali L, Kuwabara F, Zachazewski J, Browne P, Robinson B (1992) A new method for the determination of the characteristic shape of an isokinetic quadriceps femoris muscle torque curve. Phys Ther 72:585–592 discussion 593–595
48. Scudder GN (1980) Torque curves produced at the knee during isometric and isokinetic exercise. Arch Phys Med Rehabil 61:68–73
49. Kellis E, Baltzopoulos V (1997) The effects of antagonist moment on the resultant knee joint moment during isokinetic testing of the knee extensors. Eur J Appl Physiol Occup Physiol 76:253–259
50. Grace TG, Sweetser ER, Nelson MA, Ydens LR, Skipper BJ (1984) Isokinetic muscle imbalance and knee-joint injuries. A prospective blind study. J Bone Joint Surg Am 66:734–740
51. Barton LM, Bird HA (1996) Improving pain by the stabilization of hyperlax joints. J Orthop Rheumatol 9:46–51