PREVENTIVE ANKLE TAPING - EVALUATION OF MECHANICAL, NEUROMUSCULAR AND THERMAL EFFECTS BEFORE AND AFTER EXERCISE

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INTRODUCTION

Athletes and coaches in different sport disciplines use preventive adhesive tape or bandages in order to avoid ankle sprains since Paul Beiersdorf has invented tape about 100 years ago. Many authors tried to evaluate the main effects of taping in respect to its mechanical support (FUMICH 1981, GARRICK 1973 LAUGHMAN 1980, SHAPIRO 1994) to the ankle joint and its preventive effect concerning injuries in high risk sports like basketball, football, athletics or gymnastics.

Clinical studies have shown that ankle taping reduces the risk of injury although it has been demonstrated that the mechanical support does decrease even after a few minutes of practice (GARRICK 1973, SHAPIRO 1994) .

The aim of the study was to investigate the mechanical as well as the neuromuscular influence of different tape materials and techniques before and after exercise.

METHODS

12 subjects underwent 5 different trials in a randomized order:

- without tape
- with tape material A and standard tape technique (MONTAG, 1993)
- with tape material B and standard tape technique (MONTAG, 1993)
- with tape material A and special tape technique (unpublished)
- with tape material B and special tape technique (unpublished)

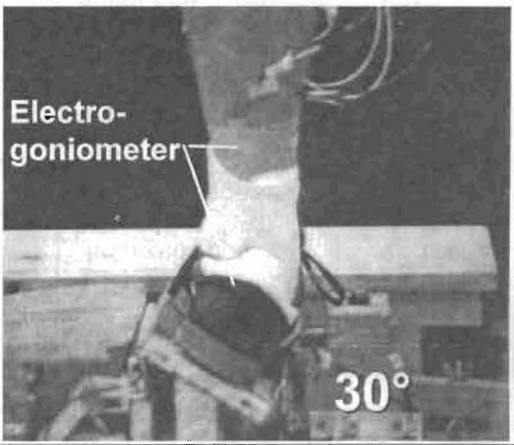
The latter tape technique was shorter than the standard technique and less tape material was necessary. Due to restriction of the measurement procedure only the right ankle was taped.

This series of exercises were used to stress the taped ankle:

- 5 Drop jumps (36 cm Height)
- 10 minutes running (tread mill)
- 3 minutes jumping using a special "jump-device" with slope surfaces (increased Inversion/eversion and Dorsal/Plantar flexion during the landing phase).

The course was performed two times. The main test was the simulated ankle Inversion injury by using a special tilt device to apply random-

Figure 1: tilt device for simulated Inversion injury



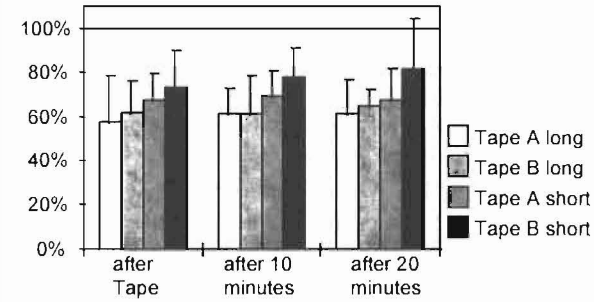
ized ankle movements (30° Inversion + 15° Plantarflexion) while the subject is standing on the tilt platform (Fig. 1). In order to reduce measurement errors, 5 measurements were taken from each condition and then all data were averaged. Axially load on the tested leg was controlled by strain gauges at the tilt device in combination with an optical feed back system. Magnitude and velocity of ankle joint motion was recorded from 2-axial goniometers (Penny&Giles).

This goniometer was placed inside the shoe directly on the skin over the Dorsal calcaneus and the Achilles tendon (Fig. 1). The values were normalized to data from that trial without tape.

Surface EMG-activity was measured from the mm. peroneus l., tibialis a., gastrocnemius and vastus medialis.

Skin temperature alterations beneath the adhesive tape were recorded after each exercise by thermocouples with an accuracy of 0.1 K. To increase reproducibility of data all measurement areas were marked at the skin by 1mm pointers.

Figure 2: maximum amplitude of Inversion angle from injury simulation normalized to the condition without tape, before and after exercise (mean + s.d. n=12)



RESULTS

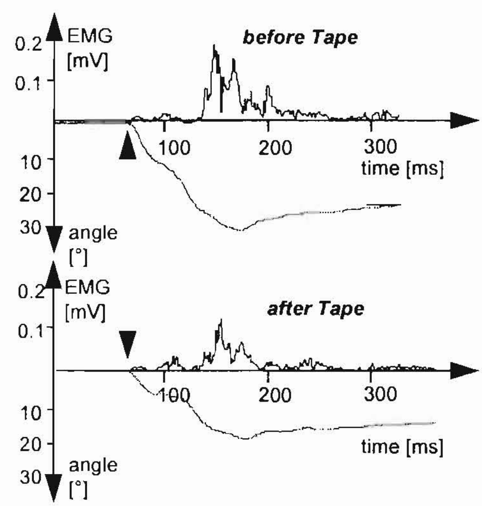
Normalized amplitude and velocity of simulated Inversion injury was initially reduced by all tapes significantly ($p<0.01$).

Difference between materials or techniques could not be found. Only tape material B in combination with the special taping technique lost mechanical stability after 20 minutes of exercise (Fig. 2).

Even without tape it was found that the maximum amplitude of the Inversion angle during the simulated Inversion injury was increased up to 6% after 20 minutes of exercise.

There is a tendency of reduced EMG-activity of both integrated EMG-activity and maximum amplitude of the signal after tape application (Fig. 3). The mean differences of the integrated EMG for all subjects were not significant.

Figure 3: example of rectified and averaged EMG pattern of the m. peronaeus and Inversion angle before and after tape application during Inversion injury simulation

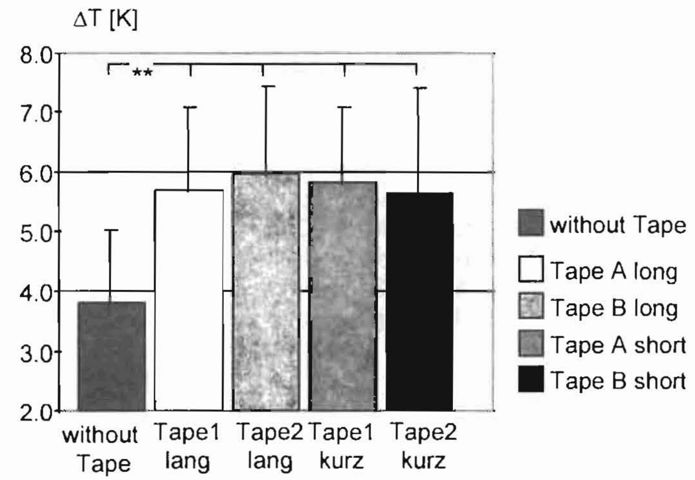


The EMG-activity during injury simulation was reduced in untaped ankles up to 12% after 20 minutes of exercise.

If the ankle was taped - the EMG-reduction after 20 minutes was at a lower level (5%).

The latency of the electromechanical response of the four measured muscles after the stimulus movement was between 65 and 70 milliseconds.

Figure 4: skin temperature of the ankle after 20 minutes of exercise (mean + s.d., n=12)



Skin temperature under the tape increased ($p<0.01$) significantly compared to untaped ankle.
There are no significant differences between the used materials and applied tape techniques.

DISCUSSION

In this study comparative data were obtained on the mechanical support as well as the neuromuscular effects of two different tape materials and two different methods of tape application before and after exercise. The preventive effect of adhesive taping is achieved at the initial exercise phase by the mechanical stabilization properties of the tested materials. This finding is contradictory to previous reports (RARICK1962, DE LACERDA 1978).

It could clearly be shown that amplitude and the velocity of the Inversion angle during a simulated Inversion injury of 30° Inversion and 15° Plantarflexion was reduced up to 60% of the value without tape. In accordance to findings published by GARRICK (1973) and SHAPIRO (1994) this could be one reason for the decreased frequency of ankle injuries if preventive tape is used.

In the later exercise phase (when the mechanical support decreases and the neuromuscular system is exhausted) the risk of injury could be reduced by the proprioceptive tape effect, which can be concluded from the EMG-activities.

The loss of mechanical stability measured by Inversion angle was at a lower level than expected from the known literature (FUMICH 1981, GARRICK 1973, SHAPIRO 1994). Possible reasons for this could be the quality of the used materials or the excellent taping technique of a well experienced physiotherapist.

The EMG response after tape application seems to be reduced - this could be interpreted with respect to the reduced angular velocity of the simulated injury movement. The reduced electromechanical responses after 20 minutes of exercise are related to muscular and physiological fatigue. But if the ankle was taped, this EMG-activity of the muscles acting around the ankle joint was at a higher level as expected from stimulating mechanical parameters (amplitude and velocity of inversion angle). With respect to these findings one can conclude that the preventive effect of adhesive ankle taping is not only due to mechanical stabilization but also due to proprioceptive neuromuscular stimulation induced by tape.

Without tape the skin temperature around the ankle joint increased up to 3 Kelvin after 20 minutes of exercise. This value was nearly doubled if tape was applied, so the mentioned proprioceptive stimulation of the neuromuscular system could be supported by increased temperature and related metabolism. Further studies should differentiate the reasons of this proprioceptive effect.

REFERENCES

1. **De Lacerda, F.G.:** Effect of underwrap conditions on the supportive effectiveness of ankle strapping with tape. Am J Sports Med, Vol. 18: 77-81, 1978.
2. **Fumich, R. M., A. E. Ellison, G. J. Guerin, P. D. Grace:** The measured effect of taping on combined foot and ankle motion before and after exercise. Am J Sports Med, Vol. 9, No. 3: 165-170, 1981.
3. **Garrick, J.G., R. K. Requa:** Role of external support in the prevention of ankle sprains. Med Sci Sports Exerc, Vol. 5, No. 3: 200-203, 1973.
4. **Glick, J.M., R.B. Gordon, D. Nishimoto:** The Prevention and Treatment of Ankle Injuries. Am J Sports Med, Vol. 4: 136-141, 1976.
5. **Laughman, R.K., T. A. Carr, E. Y. Chao, J. W. Youdas, F. H. Sim:** Three-dimensional kinematics of the taped ankle before and after exercise. Am J Sports Med, Vol. 8, No. 6: 425-431, 1980.
6. **Malina, R.M., L. B. Plagenz, G. L. Rarick:** Effect of exercise upon the measurable supporting strength of cloth and tape ankle wraps. The Research Quarterly, Vol. 34, No. 2: 158-164, 1962.
7. **Mayhew, J.L.:** Effects of Ankle Taping on Motor Performance. Athletic Training, 7: 10-11, 1972.
8. **Montag, H.J., P.D. Asmussen:** Taping Seminar. Perimed-spitta Medizinische Verlagsgesellschaft, Balingen: , 1993.
9. **Rarick, G. L., G. Bigley, R. Karst, R. M. Malina:** The measurable support of the ankle joint by conventional methods of taping. J Bone Joint Surg, Vol. 44-A, No. 6: 1183-1190, 1962.
10. **Scheuffelen, Ch., W. Rapp, A. Gollhofer, H. Lohrer:** Orthotic Devices in Functional Treatment of Ankle Sprain. Int J Sports Med, 14: 1-9, 1993.
11. **Shapiro, M. S., J. M. Kabo, P. W. Mitchell, G. Loren, M. Tsenter:** Ankle sprain prophylaxis: An analysis of the stabilizing effects of braces and tape. Am J Sports Med, Vol. 22, No. 1: 78-82, 1994.

THE EFFECT OF WRIST RESTRAINTS ON WHEELING BIOMECHANICS

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INTRODUCTION

High intracarpal pressures created by hyperextension of the wrist and repetitive high force stresses during wheelchair propulsion are suggested causes of median nerve dysfunction at the wrist/hand (Burnham & Steadward, 1994; Gellman et al., 1988; Aljure et al., 1985). An injury survey of 116 wheelchair basketball players found that the wrist and hand were the most common site of injury (Burnham, Higgins & Steadward, 1994). Prevalence of carpal tunnel syndrome has been found to range between 10% and 67% in wheelchair dependent individuals (Burnham & Steadward, 1994; Davidoff et al., 1991; Gellman et al., 1988; Tun & Upton, 1988; Aljure et al., 1985). A previous investigation (Burnham, Chan, Hazlett, Laskin & Steadward, 1994) found that wearing a foam-padded glove did not reduce wheeling induced median nerve conduction block and it was hypothesized that either the type of glove used did not provide adequate extrinsic protection to the median nerve or, alternatively, that the position of extreme wrist extension during wheelchair propulsion was the major cause of median nerve dysfunction. A better padded glove, a splint to reduce wrist extension, or a combination of both may provide greater protection to the median nerve. Such intervention, however, would not be acceptable if the wheeling mechanics became awkward or slow. The purpose of this investigation, therefore, was to assess whether various forms of hand/wrist protection (visco-elastic padded glove, wrist splint, glove and splint combined) could effectively reduce the hyperextension seen at the wrist during wheelchair propulsion, thus potentially reducing the conditions predisposing to carpal tunnel syndrome. In addition, the various forms of hand/wrist protection and their effects on wheeling mechanics were evaluated.

METHODS

The wheeling performances of thirteen subjects with prior wheeling experience were recorded using two SVHS Reporter Panasonic AG-450 videocameras. The cameras were positioned to obtain a front and side view of the subject and wheelchair. Reflective markers were placed on the joint centers of each subject at the shoulder and elbow, on the styloid processes of the radius and ulna, and on the distal ends of the 2nd and 5th metacarpals of the right limb. Each subject propelled a standard wheelchair basketball chair mounted to a set of wheelchair rollers under four different conditions: i) no protection, ii) visco-elastic padded glove, iii) wrist splint, and iv) glove and splint together. The glove ("Vibra-glove", Chatanooga Group Inc.) allowed free wrist motion and contained a visco-elastic material sewn into the palm overlying the carpal tunnel region. The splint (Hammerline Dorsal Splint) wrapped around the palmar aspect of the metacarpal joints and had a padded metal bar extending along the dorsal wrist. The design of splint was intended to immobilize the wrist, but did not provide padding over the carpal tunnel region. The combined glove and splint was created to pad the carpal tunnel, and at the same time immobilize the wrist. Under each of the conditions, subjects were videotaped as they wheeled for fifteen seconds both at their average and maximum wheeling speeds.

Twelve points surrounding the activity space were filmed prior to testing and later utilized for calibration. The direct linear transformation method (Abdel-Aziz and Karara, 1971), incorporated into the Ariel Performance Analysis System. was used for three-dimensional coordinate data reconstruction, followed by smoothing of the data using a cubic spline. Synchronization between the two views was achieved using an externally triggered LED visible to both cameras. Three-dimensional joint angular displacement-time histories for the elbow and wrist were determined using the 3D coordinate data and the dot product identity. A relative measure of wheeling speed was determined using the roller wheel's angular displacement while the subject was wheeling.

Each subject was analyzed on at least two complete wheeling cycles under all four wrist conditions. Wrist and elbow angles and joint range of motions were determined. Data were analyzed using an one way ANOVA followed by Scheffe post hoc comparisons at the .05 level of significance.

RESULTS

No significant differences were found between the conditions for the elbow angle, however significant differences were revealed for the wrist extension and wrist range of motion angles (Table 1). Both splint conditions (splint, glove & splint) were significantly different from the non-restraint conditions (no protection, glove). Wrist extension was significantly less under both splint conditions. No significant differences were found between the conditions for maximum wheeling speed.

TABLE 1

The Effect of Various Types of Hand Protection on Selected Kinematic Parameters During Wheelchair Propulsion

	Elbow			Wrist		
Type of Hand Protection	Max Flexion (deg)	Min Flexion (deg)	ROM (deg)	Max Extension (deg)	Min Extension (deg)	ROM (deg)
No Protection	86.6 (31.7)	26.3 (16.1)	65.8 (20.0)	42.7 (17.1)	10.8 (8.8)	34.8 (9.2)
Glove	97.7 (12.8)	30.3 (15.9)	67.7 (21.0)	44.6 (8.1)	12.0 (8.6)	32.6 (8.3)
Splint	97.7 (15.2)	32.6 (17.1)	65.2 (19.9)	*33.0 (10.3)	17.5 (9.6)	*15.5 (4.6)
Glove & Splint	97.2 (11.5)	30.7 (17.6)	66.4 (18.3)	*29.9 (10.2)	11.7 (8.4)	*18.2 (8.2)

* = $p < .05$

CONCLUSIONS

Within the limitations of this study, it can be concluded that the wrist restraints significantly reduced wrist extension during wheeling and that the restraints did not significantly affect wheeling mechanics as suggested by the consistent elbow-angle time histories and wheeling speeds.

REFERENCES

Abdel-Aziz, Y.I. and Karara, H.M. (1971). Direct linear transformation from comparator coordinates into object-space coordinates. Symposium on Close-Range Photogrammetry (pp. 1-18). American Society of Photogrammetry, Falls Church.

Aljure, J., Eltorai, I., Bradley, W., Lin, J., and Johnson, B. (1985). Carpal tunnel syndrome in paraplegic patients. Paraplegia, 23, 182-186.

Burnham, R., Chan, M., Hazlett, C., Laskin, J. and Steadward R. (1994). Acute median nerve dysfunction from wheelchair propulsion: the development of a model and study of the effect of hand protection. Archives of Physical Medicine and Rehabilitation, 75, 513-518.

Burnham, R., Higgins, J., and Steadward, R. (1994). Wheelchair basketball injuries. Palaestra, 10(2), 43-49.

Burnham, R. and Steadward, R. (1994). Upper extremity peripheral nerve entrapments among wheelchair athletes: prevalence, location, and risk factors. Archives of Physical Medicine and Rehabilitation, 75, 519-524.

Davidoff, G., Werner, R., and Waring, W. (1991). Compression mononeuropathies of the upper extremity in chronic paraplegia. Paraplegia, 29, 17-34.

Gellman, H., Chandler, D.R., Petrasek, J. (1988). Carpal tunnel syndrome in paraplegic patients. Journal of Bone and Joint Surgery, 70, 517-519.

Tun, C.G. and Upton, J. (1988). The paraplegic hand: electrodiagnostic studies and clinical findings. Journal of Hand Surgery, 13, 716-719.

EFFECTS OF SELECTED UNWEIGHTING CONDITIONS ON KNEE TORQUES DURING PARTIAL SQUATS WHILE TETHERED

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INTRODUCTION

This study examined the effects of different unweighting conditions on the knee torques produced while performing partial squats when tethered by an active traction Conva-Lift prototype.

METHODOLOGY

Six males were unweighted 0%, 25%, and 50% of their body weight (BWT) during a partial squat supported in a Kinney upper body vest by an active traction protoype (Conva-Lift). Reflective markers were placed on the toe, ankle, knee, hip, shoulder, elbow, wrist, and the harness strap. Four partial squats were performed while standing on a Kistler piezoelectric force plate (model 9861A) and videotaped from a sagittal view at 60 fps. The trial representing the most fluid squatting movement was digitized, the joint end points were smoothed with a low pass digital filter at a 10 Hz cut-off frequency and the kinematic variables were analyzed by the Ariel APAS software. The vertical ground reaction forces (GRF) were sampled at 500 Hz. The GRF corresponding to the time of deep crouch which represented the force applied at the foot segment and the unweighting force representing the percentage of the body weight that was applied at the shoulder harness position were entered into the APAS kinetic analysis module, in order to calculate the knee torques at the deepest squat position. From the videographic records the following kinematic variables were calculated: 1) the squat depth (descent), 2) vertical displacement of the center of mass (CM), 3) horizontal displacement of the center of mass, 4) hip angle at deep squat, 5) hip range of motion (ROM), 6) knee angle at deep squat, 7) knee ROM at deep squat, 8) ankle angle at deep squat, 9) ankle ROM, and 10) squat time. An one-way ANOVA with repeated measures on the unweighting factor was used to analyze the kinetic and kinematic data.

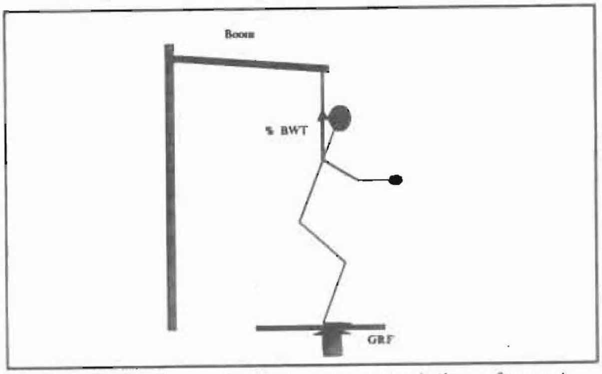

Figure 1 Kinetic model for torque calculation of squat

RESULTS

The subject's mean heigh was 175.7 ± 10.8 cm, the mean weight was 633.4 ± 151.7 N, and the mean age was 31.2 ± 6.2 yrs. Table 1 provides a summary of the kinematic variable values measured while performing a partial squat under normal BWT, 25% BWT unweighting, and 50% BWTunweighting conditions. The ANOVA analyses performed on the kinematic variables found a significant unweighting condition for the squat depth, CM vertical displacement, CM horizontal displacement, hip angle and ROM, knee angle and ROM, and ankle angle. The Conva-Lift boom arm descended 10.8 cm, 5.3 cm, and 4.6 cm for the normal squat, 25% unweighted, and 50% unweighted conditions, respectively.

The fully weighted squat resulted in a deeper squat than the tethered or unweighted squats. The subjects' CM migration demonstrated a similar vertical descent as the Conva-Lift boom for the 3 weighting conditions as shown in Table 1. When examining the horizontal CM migration during the squatting movement, a greater horizontal (forward) migration was found when squatting untethered. The differences in the horizontal CM migration between the untethered and tethered conditions resulted in a more upright squatting position which was also demonstrated in corresponding changes in the hip angle at deep squat and the ROM of the hip joint during execution of the squat. Also, smaller knee joint angles at deep squat were observed for the fully weighted squat as compared to the unweighted squat. A larger ROM for the knee joint was observed during the deeper squat for the fully weighted condition.

Significantly smaller ankle angles were found for the weighted condition than the unweighted condition which would indicate a greater degree of dorsiflexion while under full body weight. The ankle ROMs during the squatting movement were similar between the three weighting conditions and also, the times required to execute the squat for each unweighting condition were similar.

The analysis found significant differences between the knee torques at deep knee flexion ($p=.04$) represented in Figure 2, the knee torques were 163.3 ± 50.6 Nm, 106.7 ± 35.7 Nm, and 124.3 ± 26.4 Nm, for the 0%, 25%, and 50% unweighting conditions, respectively.

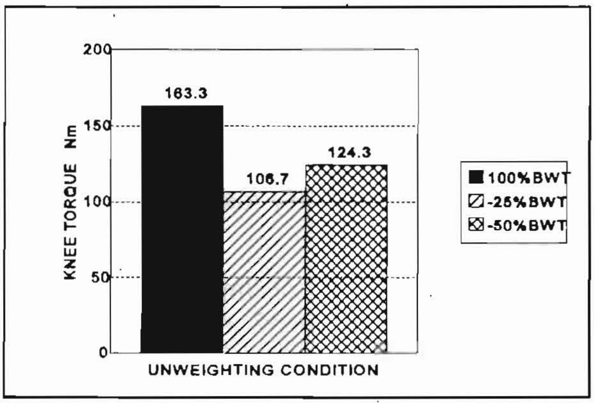

Figure 2 Knee torques during partial squats while tethered

Table 1 Selected Kinematic and Kinetic Variables During Tethered Partial Squats

Variable	Unweighting Condition 100%BWT	- 25%BWT	- 50%BWT	F Prob
Squat Depth cm	10.8±3.9	5.3± 1.2	- 4.6± 1.4	p=.003
CM Ver. Displace. cm	-8.4±4.1	-3.7±1.7	-3.5±1.5	p=.001
CM Hor. Displace. cm	5.0±2.2	3.1±2.3	0.8±2.1	p=.005
Hip Angle at Deep Squat deg	133.0±13.4	150.5±7.8	151.6±8.5	p=.005
Hip Angle ROM deg	50.9±7.6	34.2±6.9	29.8±5.9	p=.000
Knee Angle Deep Squat deg	114.1±7.2	135.0±6.5	136.9±6.0	p=.000
Knee ROM deg	50.9±7.6	34.2±6.9	29.8±5.9	p=.000
Ankle Angle Deep Squat deg	82.6±9.6	94.6±11.6	95.7±7.8	p=.000
Ankle ROM deg	21.8±7.9	14.3±3.1	13.6±2.2	p=.501
Squat Time sec	1.6±.26	1.87±.26	1.81±.4	p=.452
Knee Torque Deep Squat Nm	163.3±50.6	106.7±35.7	124.3±26.7	p=.037

These torque values are similar to the values reported by Smidt (1973), and Reilly & Martens (1972), and higher than those reported by Lunnen (1981). The combination of the increased knee flexion and increase knee torque would increase the strain placed on the anterior cruciate ligament (ACL) which would be consistent with the findings of Haynes (1990), and Schilke, Johnson, Housh & O'Dell (1996). Therefore, the reduction of knee torques observed in the tethered conditions would be beneficial in developing quadriceps strength without adversely loading the ACL.

CONCLUSION

In summary, as the degree of unweighting provided by the Conva-Lift active traction prototype was increased, a corresponding decrease in the knee torques was observed. Besides the tethering device reducing the knee torques, it also controlled the depth of squat and these factors would be beneficial in the rehabilitation of knee injuries and preventing further injury.

REFERENCES

Haynes, D., Pepe, C., Feinstein, J. & Hungerford, D., (1990). The changing excursions of the hamstring muscles during flexion, rotation, varus and valgus movements of the tibia. Proceedings of the 36th Annual Meeting of the Orthopaedic Research Society, New Orleans, Louisiana, 15:496.

Lunnen, J., Yack, J., & LeVean, B. (1981). Relationship between muscle length, muscle activity and torque of the hamstring muscles. Phys Therapy, 61:190-195.

Reilly, D., & Martens, M., (1972). Experimental analysis of the quadriceps muscle force and patella-femoral joint reaction force for various activities. Acta Orthop. Scand., 43:126-137.

Schilke, J., Johnson, G., Housh, T., & O'Dell, J., (1996). Effects of muscle strength training on the functional status of patients with osteoarthritis of the knee joint. Nursing Research, 45(2):68-72.

Smidt, G., (1973). Biomechanical analysis of knee flexion and extension. J. Biomechanics, 6:79-92.

STRENGTH TRAINING FOR POLYMYOSITIS PATIENT

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INTRODUCTION

Polymyositis is a diffuse inflammatory disease involving muscular tissue leading to a loss of power. The group of disorders is heterogeneous and rare; its incidence is probably about 3 per million population per year in the United Kingdom. The etiologic factors are poorly understood and have been claimed to be viral etiology. There are substantial evidence for the involvement of cell-mediated autoimmune damage to muscle cells.(1)

Clinical features of polymyositis presents as symmetrical weakness of limb girdle muscle, commencing from the lower girdle. Patient usually experience difficulty in rising from a sitting position, going upstairs, getting in and out of a bath and eventually getting out of bed. Wasting of muscle groups may be prominent. In some patients respiratory muscle involvement may lead to respiratory failure.

This is a disease of muscle where some or all of the muscle fibres of a motor unit do not function properly and additional motor units are recruited to provide a specific strength of contraction. In the inflammatory myopathies of polymyositis, there is segmental necrosis of a muscle cell. As a result of this process, a single muscle fibre can be divided into many individual segment of which only one segment is innervated.(2)

Strengthening exercise in the face of active myositis should be undertaken with caution because the effects of resistive exercises on the existing muscle inflammatory disease have not been adequately assessed.(3) Polymyositis is a classic example of motor unit disease that may progress, become arrested or improve. Physical treatment is based on 3 principles; 1) maintain flexibility 2) minimize pain through heat application and 3) maximal use of muscles will be the best therapy.

SUBJECT AND METHODS

Because of the rarity of the disease, only ONE female subject of 57 years of age as diagnosed by her physician to be suffering from polymyositis. Subject was under prescription of 2 prednisone (steroids) tablet per day. She was unable to sit up or perform any personal mobilization on her own without any assistance. Mobilizing any of the joints will ensue severe pain on the following day as seen in people suffering from delay onset of muscle soreness.

Approaching this experiment, it requires some extend of education to the subject. Subject was explained on the chemical and electrical phenomena of muscular contraction. She must know that for her rehabilitation, every contraction must only occur at her will. In the "Imagined Contraction" as mentioned by Enoka, R.M.,(4), this is a form of strength training without any mobilization, this is entirely different from Isometric Contraction.

In the case of polymyositis, patient must maintain flexibility. As such, we advise subject to be conscious of every movement of the joints by the contraction of the prime movers. There must be a mind and muscle connection. From the rationale of "Imagined Contraction", the adaptation in the nervous system increases spinal connection and nerve conduction at which to an extend improve the present situation due to her old age. With the improved of the spinal connection and nerve conduction, muscular tonous increases because of its specificity, each strength training exercise is an isolation movement. This type of contraction will make it more easier for the subject to perform, even the degrees of the joint displacement is small.

Transmission of impulse is targeted well based on the mind and muscle connection. As compared to normal contractions, majority of the contractures were assisted mainly by the synergistic muscle.

RESULT

No. of subject	1st. month training	2nd. month training	3rd. month training	Does of medication
1	Targeted Joints	Joint Strength Mobility	Personal	Before Training - 2 Prednisone
	Shoulder	△	Able to dress up	After Training - 1 Prednisone
	Elbow	△	Able to wash face	
	Knee	△	Able to comb hair	
	Ankle	△	Reduce Assisted Walking	

DISCUSSION & CONCLUSION

The difficulties in this experiment is the ability of the subject to concentrate on each contraction of the muscle group because every contraction and relaxation of a muscle are action series done quite subconsciously. The expression of voluntary strength and power may be linked to a skilled art of which the changes in nervous system that enhance strength is referred as neural adaptation.(5)

And because of the muscular atrophy, it is rather impossible for the subject to perform compound movement like squats, presses, etc.

This method is quite similar to electrical muscular stimulation but the whole idea is :

1) To establish the mind and muscle connection
2) To educate the patient to move the joints at will, targeting at a specific muscle at the time of training, minimizing the assistance of synergistic muscle
3) To improve spinal connection and nerve conduction
4) To maintain flexibility and mobility through mobilization
5) Not to overindulge in excessive contractures by synergistic muscle groups which could lead to elevation of creatine phosphokinase, CPK.

Because one of the key diagnosis of polymyositis is measurement of muscle enzymes, particularly CPK. CPK leaks from the muscle upon muscular exertion or inflammatory myopathies as in polymyositis. Whether this form of training elevates CPK is still unconfirmed but the results and responses demonstrated by the subject is recommendable.

REFERENCES :

1) Intergrated Clinical Science, Musculoskeletal Diease, (1984). Edited by Dickson, R.A. & Wright, V., (pp. 223-224)

2) Kottke/Lehman, Krusen's Handbook of Phy. Med. and Rehab. 4th. Ed., (1990), (pp. 97)

3) Swezey, R.L. : Arthritis : Rational Therapy and Rehab. Philadelphia, W.B. Saunders Company, (1978), (pp. 21-45)

4) Rogers, M.E., Neuromechanical Basis of Kinesiology, 2nd. Edition, (1994), (pp. 314-316)

5) G.S. Digby, Neural Adaptation in Strength and Power Training, Human Muscle Power, (1984), Proceedings from Macmaster Int'1. Symposium of Human Muscle Power. (pp. 289-307).

MUSCLE COORDINATION DURING SIDE-STEP CUTTING. CAN THE COORDINATION BE INFLUENCED BY PROPHYLACTIC TRAINING ?

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INTRODUCTION

The incidence of anterior cruciate ligament (ACL) injuries has been reported to be high during the popular team sports like soccer, basketball and team handball. The most highly risked movement in team handball has been reported to be the side-step cutting manoeuvre (Strand, 1990). Well-rehabilitated ACL-deficient athletes have been shown to have increased co-contraction about the knee joint (Walla, 1985).

Accordingly the aim of this study was to examine the effect of a prophylactic training program on the co-contraction of non-injured team handball players.

METHODS

Seventeen active male team handball players, with no history of knee joint pathology, participated in the study. The subjects were randomly assigned to a training group (n=10) and a control group (n=7). The mean age, body weight and body height for the two groups were 24.2 and 21.1 years, 84.8 and 80.5 kg and 184 and 185 cm respectively. All subjects gave informed consent to the experimental procedures.

The subjects performed the handball 'match-like' side-step cutting manoeuvre on a force platform. Prior to the recordings the subjects were allowed to get familiar with the set-up.

Electromyographic (EMG) recordings were made from the following six leg muscles all acting on the knee joint: m. vastus medialis (VM), m. vastus lateralis (VL), m. biceps femoris caput longum (BF), m. semitendinosus (ST), m. gastrocnemius medialis (GM) and gastrocnemius lateralis (GL).

An analogue-to-digital converter with a 1000 Hz sampling rate was used to collect the EMG and force plate data. 500 milliseconds before and after toe-down was sampled. Ten consecutive trials were recorded for each subject.

The subjects' maximal isometric moment of force was measured for the three muscle groups during a maximal voluntary contraction (MVC) in a Darcus dynamometer. Additionally maximal EMG amplitude for each of the six muscles were recorded. Each subject performed three consecutive MVC for each muscle group with a 2 min pause between trials.

Both the training group and the control group performed their weekly handball training sessions (2-3 times a week) and in addition the training group completed a training program designed in co-operation with a physiotherapist. The training group performed 5 different exercises under supervision, twice a week for 12 weeks. The post-training test procedure for the trained group was accomplished 2-3 days after the final special training session.

The exercises consisted of 1) maximal one-legged jumps to the side with fixed number of repetitions, 2) one-legged squats, 3) hamstring pulls, 4) hip abductions, 5) one-legged 'coordination jumps' for one minute. Exercise 2-4 were performed until exhaustion. The exercises were designed in a progressive manner by increasing the strain on the athletes twice during the training period.

The number of repetitions of exercises 2-5 was recorded during every training session and the mean of the repetitions in the second and third training session was used as pre-training values and compared with the number of repetitions at a test with the same relative load as at the start of training, 15 min. after the post-training test.

The force platform data were converted to Newton and the vertical ground reaction force (VGRF) was used for analysis. The peak forces and the duration of the ground contact phase were recorded. Due to the special shape of the VGRF it was possible to divide the ground contact phase into two sections. Gollhofer (1991) has shown, that the highest amplitude of the second top can be used as the instant at which the eccentric landing phase is changed into the concentric push-off phase. The duration of the landing phase and push-off phase were recorded, and the landing impulse and push-off impulse were calculated by time integration of the VGRF. The centre of pressure (COP) was calculated and the variation of COP during the landing phase was analysed.

All the EMG-recordings were highpass filtered at 25 Hz, rectified and lowpass filtered at 32 Hz. The highest amplitude found after filtering of the MVC EMG's was selected for normalisation. The EMG-signals of the ten trials of each subject recorded during the side-step cutting were averaged and normalised to the MVC EMG's. The onset of EMG relative to toe-down, instant of peak EMG amplitude relative to toe-down and peak ground reaction force, amount of EMG before toe-down (pre-activity IEMG) and HAM/QUA ratio of pre-activity IEMG were dertermined

RESULTS

An initial steep increase of VGRF was evident and resulted in a peak with a mean of 2500 N (± 600 N). This peak appeand about 40 ms. after toe-down. A second peak with a mean of 2200 N (± 230 N) was also evident after 100 ms.

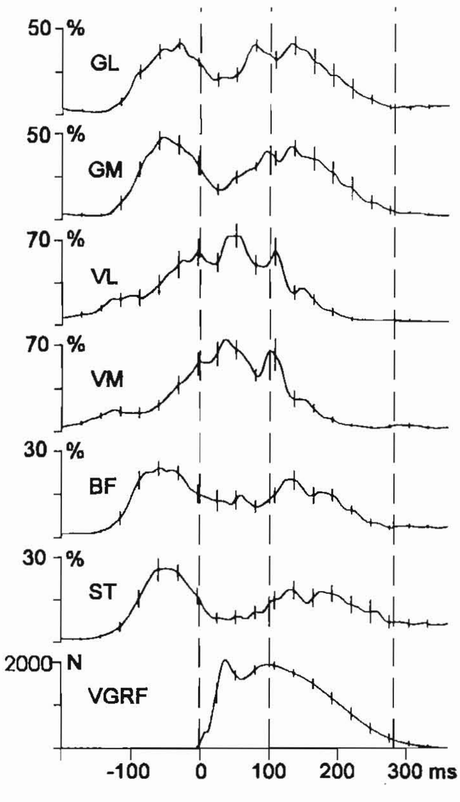
Mean duration of the stance phase was 298 ms in the training group. The first part, the landing phase, lasted 100 ms.

The force platform results showed that the training group had a significantly shorter stance phase after the training period. The shorter stance phase was found to be due to a shorter push-off phase. There was no change in the duration of the landing phase. This reduction in push-off phase may be due to a better neuromuscular coordination producing a more forceful knee extension in the beginning of the push-off phase. Even though the duration of the push-off phase was shorter there was no change in the push-off impulse. This may be explained by an insignificant (p=0.09) increase of the amplitude of the second peak of the vertical ground reaction force. Yet, no changes were observed in the EMG-signals of the knee extensors or the gastrocnemius muscles. The reason could be, that the EMG-analysis was not adequately sensitive to register these probably very small changes in muscle activation. No changes were observed in the magnitude of the first peak.

In an attempt to measure the overall stability of the joints during the landing phase, the centre of pressure (COP) was calculated during the landing phase. Tropp (1985) found a correlation between the variation in COP during a standardised test and the frequency of ankle sprains in soccer. In the present study no changes was found after the training period. The improvement in balance recorded in exercise 5 did apparently not affect the balance during the side-step cutting.

The overall EMG-pattern during side-step cutting was quite similar among the subjects. There was a characteristic difference in the shape of the EMG patterns between the knee extensor muscle group and the two knee flexor muscle groups, showing an alternating activity between the two groups. See figure 1.

One of the main features of EMG-pattern during the side step cutting manoeuvre was the early onset of the EMG-activity. This pre-activity EMG indicated that the central nervous system was prepared for the impact that followed. The pre-activity period of the semitendinosus muscle of the training group was significantly shorter ($p<0.05$) after the training period, while the m. biceps femoris showed an insignificantly shorter pre-activity period ($p=0.051$) after the training period. Dyhre-Poulsen (1987) has showed, that in very talented gymnasts, the periods of activity were more precisely timed to the landings during a split leap. This indicated that the technical quality of the jump was higher in the gymnasts with shorter periods of activity. A shorter pre-activity period does not necessarily mean less force development, since Gollhofer (1987) showed, that it is the rise in EMG-amplitude, and thereby the increase in IEMG, correlates with the impact to come. In the present study, there was no changes in IEMG, in spite of the later onset of EMG-activity in the hamstring muscles.



Figur 1 shows a representative EMG pattern from the pre-training test together with the corresponding vertical force component.

The hamstring muscles and the gastrocnemius muscles showed a peak activity about 45 ms. before toe-down while the activity of the VM and VL was rising during the same period. The peak relative activity of the hamstring muscles was about 30 % and no changes were observed after training. The EMG-activity of the knee extensors was at the same time only about 35 % of maximum activity. Considering an electro-mechanical delay of 50 ms, the peak force development of the ACL-protective hamstring and gastrocnemius muscle groups occured at toe-down. The HAM/QUA-ratio (amount of co-contraction) was maximal at toe-down. Since especially the hamstring muscles, due to the anatomical position, have a great influence on knee rotations and anterior shear forces during knee flexion, this must be an important feature of the muscle coordination in order to prevent injuries caused by incorrect knee angles or knee rotations during the impact.

The HAM/QUA-ratio did not change after the training period. The reason may be, that the proprioceptive feed-back, which is thought to modulate the motor programmes controlling the movements, was not strong enough in non-injured subjects. The coordination of the side step cutting manoeuvre seems to be optimal in non-injured subjects with a long history of performing the movement.

The VM and VL reached peak activity at about 45 ms. after toe-down and considering the EMD the peak knee extensor activity correlates with the time at which the eccentric landing phase is changed to the concentric push-off phase.

There was a significant increase in the number of performed training repetitions in all exercises except exercise 1, where the number of repetitions was fixed. This indicates an improvement of endurance in exercises 2-4 (65 %, 105% and 45 %, respectively) and an improved ability to repeatedly catch the balance during one-legged jumping in exercise 5 (115 %). As discussed earlier this improved balance did not show in the measurement of COP during the side step cutting. The reason may be that the exercise was too different from the actual side step cutting, and thus no transfer of neural learning could be detected.

The increase in endurance may influence the ability to perform the cutting manoeuvres with smaller risks later in a match.

CONCLUSION

The present study showed that it is possible to alter the timing of the hamstring muscles with respect to ground contact during a side-step cutting manoeuvre. The pre-activity period was shorter after 12 weeks of training twice a week with a specially designed training program. Yet, the amount of pre-activity IEMG was not altered, neither was the HAM/QUA-ratio. It is concluded, that the co-contraction of the knee muscle groups during a side-step cutting manoeuvre is optimal in athletes with no previous history of knee pathology. The training did improve the endurance of the involved muscle groups, and it is possible that this will have an influence on the ability to perform the side-step cutting manoeuvre with optimal coordination later in the match.

REFERENCES

Dyhre-Poulsen, P. (1987). Analysis of splits leaps and gymnastic skill by physiological recordings. Eur. J. Appl. Physiol., 56, 390-397.

Gollhofer, A. (1987). Innervation characteristics of m. Gastrocnemius durin landing of different surfaces. Biomechanics X-b. Ed: Jonsson, B., 701-705.

Gollhofer, A., Kyröläinen, H. (1991). Neuromusclar control of the human leg extensor muscles in jump exercises under various stretch-load conditions. Int. J. Sports Med., 12, 34-40.

Strand, T., Tvedte, R., Engebretsen, L., Tegnander, A. (1990). Anterior cruciate ligament injuries in team handball. Tidsskr. Nor. Lægeforen., 110, 2222-2225. (Norwegian).

Tropp, H. (1985). Functional instability of the ankle joint. Dr. Thesis. Linköping University Medical Disserations. Linköping, Sweden.

Walla, D.J., Albright, J.P., McAuley, E., Martin, R.K. Eldridge, V. El-Khoury, G. (1985). Hamstring control and the unstable anterior cruciate ligament-deficient knee. Am. J. Sports Med., 13, 34-39.

A 3-D KINEMATIC STUDY OF TWO POPULAR FLEXIBILITY TESTS

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INTRODUCTION

Flexibility is the intrinsic property of body tissues which determines the range of motion achievable without injury in a joint or group of joints (Holt et al. 1995). Although empirical evidence is not conclusive, it is generally agreed that flexibility is an important physiological variable in sport. Recently, a more rigorous scientific approach to the area of flexibility has been taken by researches who have directed efforts toward developing and validating improved static flexibility measurement procedures (Ekstrand et al., 1982) and addressed questions related to the importance of flexibility to sport and appropriateness of training (Ekstrand & Gillquist, 1982).
Goniometers are often used to measure the range of motion of the joints. These devices have been criticized and their reliability questioned. Part of the problem is with the instruments and part with the procedure for using them. To deeply understand the phenomenon of flexibility more accurate, precise, multiaxial measurements are desirable. By using an automatic motion analyzer (accuracy 1/3000 the field of view), it was the purpose of this study to perform a 3-D analysis of two popular flexibility tests. When possible, the data were compared with those obtained by standard goniometers.

METHODS

Five recreational athletes (age range: 24-40 yr.; height range: 1.70-1.76 m.) with normal lower limb function and physical examinations provided informed consent and participated in this study. They were required to perform the sit and reach test and the passive single-straight-leg raising test (table 1 and 2). Both the tests are usually used as a test for hamstring tightness even if the sit and reach test combines back and hamstring flexibility. Before the measurements the subjects warmed-up by performing 10 minutes of slow jogging, and slow stretching movements. Ten trials for each exercise were executed with one-minute rest period between trials. Kinematic data were recorded by means the ELITE optoelectronic system (Ferrigno & Pedotti, 1985) with a sampling rate of 100 Hz. Markers were placed on: C7, T3, T6, T9, T12, L3, and S1 to reconstruct the spine morphology; sacro-iliac spines, iliac crests, great trochanters, femoral condiles, malleola, and fifth metatarsal heads to mark the pelvis and the lower limbs; acromions, elbows and wrists to mark the arms.
The position of the internal joint centers of the hip, knee and ankle were estimated from the position of external landmarks using a mathematical model designed to match feasibility with accuracy and whose inputs were anthropometric and kinematic data. Due to the inevitable simplifications introduced, the use of the model is constrained to movement in which large rotation of body segments around their longitudinal axes are negligible like running, cycling and vertical jumping exercises. The back profile was modelled using a cubic spline.

STARTING POSITION	The subject sits on the floor with the legs extended and the feet together. The feet are in the neutral position.
MOVEMENT	The subject bobs forward four times trying to touch as far down the legs as possible and holds a maximum position.
CAUTION	The knee must remain extended and the foot in the neutral position

Table 1. The sit and reach test

STARTING POSITION	The subject lies in a supine position on a bench
MOVEMENT	The therapist moves the leg in an arc upward and toward the forehead as far as possible
CAUTION	The knee must remain extended and the back flat on the bench throughout the movement. Care must be taken to stabilize the pelvis

Table 2. The passive straight-leg raising test

RESULTS

Mean and standard deviation values of the hip range of motion during the sit and reach and the straight-leg raising test are outlined in table 3 and 4, respectively. Values ranged from 36.3 to 72.5 and from 35 to 57.7 degrees in the former and in the latter test, respectively.

	S1	S2	S3	S4	S5
RIGHT	72.5±1.6	51±0.7	42.1±0.6	62±1.1	58.2±1.5
LEFT	66.1±1.1	56.2±1	36.3±0.7	60.2±1	53.9±1.3

Table 3. The values are in degrees.

	S1	S2	S3	S4	S5
RIGHT	50.8±0.9	46.1±1	39.6±0.5	56.3±0.6	52.3±1.1
LEFT	46.3±1.2	49.2±0.7	35±0.6	57.7±0.4	49.2±1.2

Table 4. The values are in degrees

The results showed significant bilateral differences for most of the parameters examined suggesting that evaluative procedures requiring controlateral comparisons may be inaccurate.

During the sit and reach test the subjects were instructed to try to keep their knee extended and the foot in the neutral position. In Fig. 1 and 2 the knee and the ankle joint angles at the maximum stretch position for a representative subject are presented. As it can be seen in most of the trials the subject was not able to keep the knee completely extended.

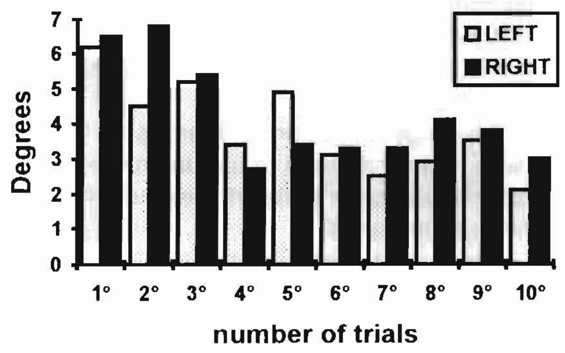

Fig. 1. Flexion of the knee joint at the maximum stretch position in the sit and reach test for a subject of this study. Zero degrees = knee extended.

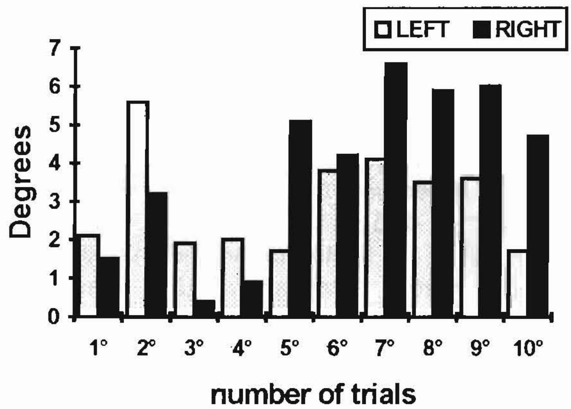

Fig. 2. Dorsiflexion of the ankle joint at the maximum position in the sit and reach test for a subject of this study. Zero degrees = foot in neutral position.

The dynamic examination of the sit and reach exercise revealed large intersubjects differences in the way to come to the full extended position evidentiating a different degree of spine mobility among the subjects.
Analyzing the straight-leg raising test the comparison with standard goniometer measurements showed differences up to 24 degrees in the hip range of motion. With regard to the sit and reach test the comparison with goniometry is not possible because the traditional protocol involves linear measurements of the distance between the fingertips and a zero mark on the floor and does not provide a direct quantification of range of motion in degrees (Twomey & Taylor, 1979).

CONCLUSION

Given the present state of knowledge and the results presented in this work, there are several basic reasons for recommending the use of an optoelectronic automatic motion analyzer for flexibility measurements:

1. It provides accurate, precise and multiaxial measurements.
2. It gives a good representation of the subjects during all the phases of the flexibility tests.
3. It provides a direct quantification of the range of motion in degrees.
4. It facilitates the work of the tester who no longer need to use instruments such as flexometers and goniometers and try aligning arms of these devices with segments while they are moving through the range.
5. It can provide the measurement of several joints and joint actions.
6. It allows the control of compensatory movements.
7. It allows a permanent record of the trials.
8. Considering the complexity of measurements performed and the amount of information available the method is not excessive time-consuming. In the present study it took less than 20 minutes for athletes preparation and trials performing.

REFERENCES

Ekstrand, J., & Gillquist, J. (1982). The frequency of muscle tightness and injuries in soccer players. American Journal of Sports Medicine, 10, 75-78.

Ekstrand, J., Wiktorsson, M., Oberg, B., & Gillquist, J. (1982). Lower extremity goniometric measurements: A study to determine their reliability. Archives of Physical Medicine and Rehabilitation, 63, 171-175.

Ferrigno, G., & Pedotti, A. (1985). ELITE a digital dedicated hardware for movement analysis via real time TV signal processing. IEEE Transaction Biomedical, 32, 943-950.

Holt, J.B., Holt, L.E., & Pelham, T.W. (1995). Flexibility: a definition, research, the future. Communication presented at the XIII International Symposium on Biomechanics in Sports. Thunder Bay, Ontario, Canada.

Twomey, L., & Taylor, J. (1979). A description of two new instruments for measuring the ranges of sagittal and horizontal plane motions in the lumbar regional. Australian Journal of Physiotherapy, 25, 201-203.