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PROTEIN SUPPLEMENTATION OF THE DIET IMPROVES THE RESULTS OF REHABILITATION FOLLOWING KNEE ARTHROSCOPIC SURGERY IN COMPETETIVE SOCCER PLAYERS

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SUMMARY

Efficient rehabilitation of the quadriceps femoris muscle in convalescence is the cornerstone of full recovery following immobilization and surgery of the knee. Wide variety of kinesitherapeutic protocols have been described and used in order to ensure the athlete's rapid return to sports. The aim of this study was to investigate whether protein supplementation of the diet after arthroscopic surgery of the knee and during application of a complete kinesitherapeutic program is beneficial for the patient. A total of 56 patients, all competitive soccer players, were recruited for the study. Of these, 47 had undergone arthroscopic surgery for meniscal repair and nine for ACL reconstruction. They were randomized into two groups of 28 patients each - experimental (EG) and control (CG). Identical kinesitherapeutic protocols were applied for both groups. All patients received the similar standard diet; in addition to this diet, the EG patients received 1 g/kg/day of high-quality milk and egg protein supplement (90.5 % protein content). Kinesiological evaluation of the knee joint condition was carried out by myotonometry (MTM) of the quadriceps muscle, thigh circumference (TC) measurement, range of motion in the knee joint, and manual muscle testing (MMT) at the injured and uninjured side before and after the trial. Statistical analysis was performed with the Student's t-test (data were presented as mean ± SD). At the end of the experiment, the injured leg TC was closer to the uninjured leg TC in the EG patients (47.2 ± 2.1 vs 47.6 ± 2.6 cm, $p>0.05$) than that in the controls (46.7 ± 2.5 vs 48.4 ± 2.8 cm,

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p<0.05). Also, MTM during contraction of the quadriceps of the injured limb revealed closer values to those of the uninjured limb in the EG patients (113.1 ± 5.6 vs 114.6 ± 4.1 units, p>0.05) than those of the control group patients (88.8 ± 7.7 vs 115.9 ± 4.4 units, p<0.001). The EG patients displayed better MMT scores at the end of trial than the CG patients (4.99 ± 0.05 vs. 4.33 ± 0.26, p<0.001). The results of the study suggest that protein supplementation of the diet during kinesitherapy can beneficially contribute to the successful management of quadriceps hypotrophy after knee arthroscopic surgery of soccer players.

Keywords: Knee arthroscopic surgery, rehabilitation, quadriceps muscle, myotonometry, manual muscle testing

ÖZET

PROTEİN DESTEKLİ DİYET, FUTBOLCULARDA ARTROSKOPİK DİZ CERRAHİSİ SONRASI REHABİLİTASYON SONUÇLARINI GELİŞTİRİYOR

Dizin immobilizasyonu ve cerrahisi sonrası quadriceps femorisin etkin rehabilitasyonu sağaltımın köşe taşıdır. Sporcunun spora çabuk dönüşünü sağlamada çeşitli kineziterapötik protokoller tanımlanmıştır. Bu çalışmada amaç artroskopik diz cerrahisini takiben ve tam bir kineziterapötik programın uygulanması sırasında diyetin proteinle desteklenmesinin hasta için yararını araştırmaktı. Tamamı müsabık futbolcu olan 56 sporcu çalışmaya alındı. Bunların 47'si menisküs tamiri, dokuzu ise ACL rekonstrüksiyonu için artroskopik cerrahiye alınmıştı. Denekler 28'er kişilik deney ve kontrol gruplarına rasgele ayrıldılar. Her iki gruba da aynı kineziterapötik protokol uygulandı. Tüm hastalar benzer standart diyeti aldılar. Buna ek olarak deney grubu 1.0 g/kg/gün yüksek kalitede süt-yumurta proteini (% 90.5 protein içerikli) suplementi tüketti. Her iki diz ekleminin çalışma öncesi ve sonrasında kineziyolojik değerlendirmesi quadricepsin myotonometrisi, bacak çevre ölçümü, diz eklem hareket açıklığı ve manüel kas testleriyle gerçekleştirildi. Veriler ortalama ve standart sapma olarak verilip istatistik analiz Student t-testi aracılığında gerçekleştirildi. Çalışmanın sonunda bacak çevresi için ameliyatlı-sağlam bacak farkı deney grubunda (47.2 ± 2.1 vs. 47.6 ± 2.6 cm, p>0.05) kontrol grubuna (46.7 ± 2.5 vs. 48.4 ± 2.8 cm, p<0.05) oranla daha azdı. Bu durum, kasılma sırasındaki miyotonometri için de geçerliydi (Deney grubunda 113.1 ± 5.6 vs 114.6 ± 4.1 ünite, p>0.05; kontrol grubunda 88.8 ± 7.7 vs 115.9 ± 4.4 ünite, p<0.001). Deney grubu hastaları çalışma sonunda manüel kas testi açısından da kontrol grubundakilere oranla

daha iyi sonuçlar gösterdiler (4.99 ± 0.05 vs. 4.33 ± 0.26, p<0.001). Çalışmanın sonuçları, futbolcularda artroskopik diz cerrahisini takiben uygulanan kineziterapi boyunca diyetin protein ilavesiyle desteklenmesinin quadriceps hipotrofisinin engellemesine katkıda bulunabileceğini düşündürmektedir.

Anahtar sözcükler: *Artroskopik diz cerrahisi, quadriceps kası, rehabilitasyon, myotonometri, manüel kas testi*

INTRODUCTION

Knee injuries are among the most common injuries sustained by athletes, while meniscal lesions and anterior cruciate ligament (ACL) tears are the most common injuries of soccer players (19). Treating knee injuries by partial arthroscopic menisectomy or by meniscal repair allows patients to be able to walk without support within one to three days after surgery, resume athletic training by two to three weeks and return to competition in three to four weeks (16). Following arthroscopic repair of an ACL rupture, rehabilitation procedures aim at the rapid return of the athlete to sports participation within 10 to 12 months (12). As these two types of injuries affect commonly professional soccer players, it is of vital importance to apply intensive kinesitherapeutic procedures to shorten the convalescence period by managing effectively the hypotrophy and the reduced capacity of the quadriceps, two conditions which most often accompany these injuries (2,13,15). Rehabilitation of the quadriceps femoris muscle is the cornerstone of full recovery after inactivity, immobilization or surgery of the knee (1,9). Muscle strengthening programs include pain-free exercises, which provide a faster progression of treatment and shorter rehabilitation period.

Various types of rehabilitation programs have been described and used with the main purpose of recovering the structure and function of the quadriceps and strengthening the knee joint (6,10,11,17,18,22). However, in spite of the wide variety of therapeutic procedures proposed by different authors, there have been no studies yet on the effect of high protein supplements included in the diet targeted at improving the results of the specific treatment by managing the quadriceps hypotrophy and strengthening the knee joint on the trauma-affected side.

The present study aimed at comparing the results of two rehabilitation programs – with and without protein supplements in the

patient's diet. We also assessed whether it is expedient to use protein supplementation in restoring the structure and function of the quadriceps after arthroscopic intervention in order to facilitate the adequate return of soccer players to active sports.

MATERIAL AND METHODS

Patients: Our study sample included 56 competitive soccer players (aged 24.0 ± 4.3 years, 79.0 ± 5.3 kg) who had previously undergone arthroscopic knee surgery because of trauma (47 patients with meniscal injury, seven patients with anterior cruciate ligament rupture, and two with knee injury of other type). The time elapsed from the traumatic incident to the actual performance of arthroscopy was different for the different patients (from several days to several weeks) but all patients had pronounced hypotrophy and reduced capacity of the quadriceps as a result of the sparing regimen and the immobilization of the knee joint. The patients were allocated to two groups: experimental (n=28) and controls (n=28). Both groups were subjected to an identical postoperative rehabilitative program. Unlike the controls, however, the experimental group received daily high-protein dietary supplement in addition to the standard and controlled diet.

Diet and dietary supplementation: All patients received an identical controlled diet: 800 ± 300 kcal/24 h (11.7 ± 1.3 MJ/24 h). The experimental group patients received in addition a high-protein milk-egg supplement (Table 1) by 1.0 g/kg body weight per day during their rehabilitative program. The supplement contained a combination of milk whey and egg proteins with high assimilability and biologic value (Protein efficiency ratio = 3.30) (4,24).

The amino acid content of the supplement was balanced using the method of linear optimization of the content of nutritional mixtures (5), the essential amino acids comprising 44.0 % and the branched-chain amino acids 18.7 % of the total.

Rehabilitation program: The rehabilitation program was identical for both groups. It started on the first day and continued until day 40 following operation. The program was realized in three stages (Table 2): stage I – from the day following surgery to day 12, stage II – day 13 to day 20, and stage III – day 21 to day 40.

Table 1. Total chemical (g/100 g of product) and amino acid (g/100 g of protein) composition of the high-protein dietary supplement.

Protein	90.5
Fats	1.0
Carbohydrates	2.4
Salts and vitamins	2.1
Moisture	4.0
Energy (kJ)	1 640.0

Essential amino acids		Non-essential amino acids	
Valine	5.5	Alanine	4.4
Isoleucine	5.1	Arginine	6.6
Leucine	8.1	Aspartic acid	10.3
Lysine	6.8	Glycine	3.4
Methionine	2.1	Glutamic acid	17.5
Cystine	1.5	Proline	5.2
Threonine	4.5	Serine	5.7
Tryptophan	1.3	Histidine	2.9
Tyrosine	3.9		
Phenylalanine	5.2		

Knee joint and quadriceps muscle assessment: To evaluate the mobility of the knee joint we used standard anglemetry. The functional state of the quadriceps femoris muscle was evaluated by myotonometry (MTM) at rest and at maximal isometric contraction with myotonometer (Szirmai, Hungary) and by manual muscle testing (MMT) (3,8,14). Hypotrophy severity and muscle recovery after it were determined by measuring the circumference of the thigh. All parameters were measured at the beginning and at the end of the experiment in both the injured and uninjured legs by the same research team.

Statistics: Statistical indices were computed for each group and for all variables (StatView 4.51 Statistical Software, Abacus Concepts Inc, Berkeley, California, USA). Student's t-test was performed. All data are presented as mean (± SD). Values at the 0.05 level were accepted as being statistically significant.

Table 2. Rehabilitation program for the patients of the experimental and control groups.

Stage I (Day 1 to day 12 postoperatively)	Stage II (Day 13 to day 20 postoperatively)	Stage III (Day 21 to day 40 postoperatively)
A. Days 1 and 2: - Active flexion of knee joint to 50°. - Isometric contractions of quadriceps femoris muscle. - Mobilization of the patella. - Isotonic contractions including the antagonists and muscles in the hip joint and the tibia. - Contralateral contractions. - Passive movement therapy: elevation of the leg combined with cryotherapy and isometric muscle contractions. - Instruction how to walk unaided. **B. Day 3 to day 12:** - Active flexion of knee joint to 90°. - Continuation of kinesitherapy started in A - Suspension therapy – resorptive and trophic technique. - Cryotherapy with a metal tube and a percutaneous application drug. - Electric stimulation of quadriceps femoris muscle, superimposed technique with no resistance.	- Active full flexion of knee joint - Pulley therapy for quadriceps femoris muscle - Superimposed electric stimulation against a resistance of 2% of body weight at the beginning and 4% of body weight at the end of stage II - Cycle ergometry - Manual and subaquatic massage	**A. Day 21 to day 25** - Continuation of kinesitherapy started in stage II. - Superimposed electric stimulation of quadriceps femoris muscle against a resistance of 5% of body weight, amplitude 0° - 30° - Pulley therapy for quadriceps femoris muscle - Cycle ergometry - Swimming **B. Day 26 to day 30** - Superimposed electric stimulation of quadriceps femoris muscle against a resistance of 7% of body weight, amplitude 0° - 30°, 3 cycles. - Pulley therapy for quadriceps femoris muscle –submaximal technique. - Cycle ergometry - Individual running program - Swimming - Fitness exercises **C. Day 31 to day 40** - Superimposed electric stimulation of quadriceps femoris muscle against a resistance of 7% of body weight, amplitude 0° -90°, 3 cycles. - Pulley therapy for quadriceps femoris muscle –hypertrophic technique. - Cycle ergometry - Swimming - Fitness exercises - Long-distance running

RESULTS

Thigh circumference of the injured and uninjured limb (Table 3): Measuring thigh circumference of the injured limb and comparing it with that of the uninjured limb assessed the severity of quadriceps hypotrophy and its successful management during rehabilitation. The circumference of the injured limb thigh in the experimental group at baseline was significantly smaller than that of the uninjured limb (44.1 ± 2.0 vs 47.5 ± 2.3 cm, $p<0.001$), with a mean difference of 3.6 ± 0.8 cm between the two limbs. There was also a significant difference between the baseline values of the injured and uninjured limbs of the controls (44.9 ± 2.4 and 48.6 ± 2.9 cm, respectively, $p<0.001$) with a mean difference of 3.8 ± 0.8 cm between them.

At the end of experiment, however, thigh circumferences of the injured and uninjured limbs of the experimental group patients became equal (47.2 ± 2.1 vs 47.6 ± 2.6 cm, respectively, $p>0.05$), with a non-significant difference of 0.4 ± 0.4 cm between them. Thigh circumference of the injured limb of the controls at the end of experiment remained smaller than that of the uninjured limb (46.7 ± 2.5 vs 48.4 ± 2.8 cm, $p<0.05$), retaining a significant difference of 1.8 ± 0.8 cm between them.

Myotonometry of the quadriceps of the injured and uninjured limb (Table 4):

a. MTM at contraction: At the beginning, the m. quadriceps femoris tonus of the injured limb in the experimental group during contraction was significantly lower than that of the uninjured (73.8 ± 11.6 vs 113.2 ± 5.5 units, respectively, $p<0.001$) with a difference of 39.4 ± 14.0 units between them. This baseline characteristic in the control group patients was 47.2 ± 6.9 units (68.9 ± 6.7 vs 115.8 ± 4.5 units, respectively, $p<0.001$). At the end of experiment, the controls retained the same significant difference of 26.7 ± 9.9 units in this parameter (88.8 ± 7.7 vs 115.9 ± 4.4 units respectively, $p<0.001$); the difference in the experimental group receiving the protein supplement was negligible: 2.4 ± 3.2 units (113.1 ± 5.6 vs 114.6 ± 4.1 units, $p>0.05$).

b. MTM at rest: There was no difference between the quadriceps tonus at rest at the beginning and end of experiment in both the experimental and control groups.

Table 3. Thigh circumference (cm) of the injured and uninjured limbs of the patients of the experimental and control groups at the beginning and end of trial.

Variable	Experimental group		Control group		Differences between the groups			
	Beginning of trial (1)	End of trial (2)	Beginning of trial (3)	End of trial (4)	P1-P2	P3-P4	P1-P3	P2-P4
Thigh of the injured leg	44.1 ± 2.0	47.2 ± 2.1	44.9 ± 2.4	46.7 ± 2.5	0.001	0.01	NS	NS
Thigh of the uninjured leg	47.5 ± 2.3	47.6 ± 2.6	48.6 ± 2.9	48.4 ± 2.8	NS	NS	NS	NS
Differences between legs	3.57 ± 0.78	0.41 ± 0.41	3.8 ± 0.8	1.8 ± 0.8	0.001	0.001	0.001	0.001

Table 4. MTM (units) of m. quadriceps femoris of the injured and uninjured limbs of the patients of the experimental and control groups at the beginning and end of trial.

Variable	Experimental group		Control group		Differences between the groups			
	Beginning of trial (1)	End of trial (2)	Beginning of trial (3)	End of trial (4)	P1-P2	P3-P4	P1-P3	P2-P4
MTM at contraction for the injured leg	73.8 ± 11.6	113.1 ± 5.6	68.9 ± 6.7	88.8 ± 7.7	0.001	0.001	NS	0.001
MTM at contraction for the uninjured leg	113.2 ± 5.5	114.6 ± 4.1	115.8 ± 4.5	115.9 ± 4.4	NS	NS	NS	NS
MTM difference at between legs	39.4 ± 14.0	2.4 ± 3.2	47.2 ± 6.9	26.7 ± 9.9	0.001	0.001	0.05	0.001
MTM at rest for the injured leg	60.3 ± 7.3	61.6 ± 5.6	55.6 ± 3.7	55.6 ± 2.7	NS	NS	0.01	0.001
MTM at rest for the uninjured leg	62.4 ± 5.5	62.8 ± 5.9	55.8 ± 3.7	55.9 ± 3.5	NS	NS	0.001	0.001
MTM difference at rest between legs	2.14 ± 4.58	1.21 ± 1.99	0.14 ± 4.80	0.28 ± 2.59	NS	NS	NS	NS

Manual muscle test (MMT) of m. quadriceps femoris (Fig 1): Muscle strength of the quadriceps muscle was assessed with the manual muscle test. Three examiners performed the test. The patients from the experimental group exhibited an increase of knee extension strength on manual muscle testing from grade 3.66 ± 0.12 to grade 4.99 ± 0.55 at the end of trial ($p<0.001$). Also significant ($p<0.001$), but to a smaller degree, was the increase of the muscle strength in the patients of the control group: from grade 3.57 ± 0.12 to grade 4.33 ± 0.26 at the end of experiment.

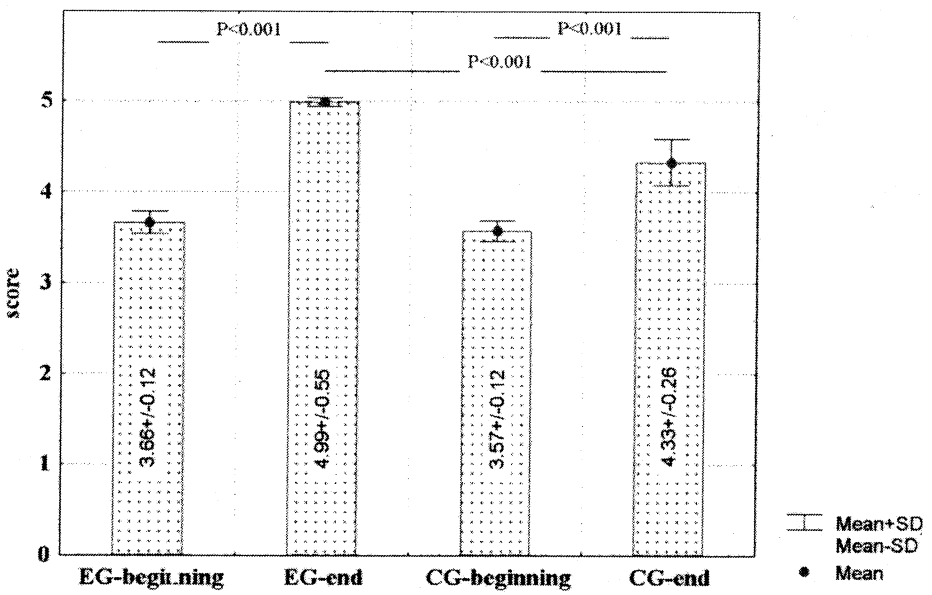

Fig 1. MMT score of the quadriceps muscle of the experimental (EG) and control (CG) groups at the beginning and at the end of the trial.

DISCUSSION

The characteristics of the patients of both groups, established immediately after operation are quite typical of the cases of pronounced quadriceps hypotrophy observed in knee injuries of long duration (1,9,11,16,17,21). At the beginning of the experiment, there was no difference between the two groups in the severity of hypotrophy assessed by the circumference of the thigh of the injured leg – 44.1 ± 2.1 cm for the controls versus 44.9 ± 2.4 cm for the experimental group ($p>0.05$). At the end of trial, the hypotrophy was successfully managed in both groups by the kinesitherapeutic program, the thigh circumference of the

group receiving protein supplement being larger by 7.1 % (only by 3.9 % in the controls) and equal to that of the uninjured leg.

It is well known that supplementing the diet with protein, especially one with a high value (Protein efficiency ratio > 3.0), realized along with systematic physical exercise, can effect an increase in the protein anabolism and bring about considerable muscle hypertrophy (23). An increase in growth performance (including muscles) could be achieved through improved protein quality. This is usually obtained by supplementing the diet with the limiting amino acids. More generally, adjusting supplies of essential amino acids to an 'ideal' protein pattern should be a way of expressing completely the growth potential of muscles. In our case, the experimental group received supplement to the diet of 0.9 g/kg/day (~100 % RDA) of protein (20). Possible relationships between changes in protein turnover after protein supplementation and hormone concentrations (e.g. insulin, IGF-1 and glucocorticoids) have been discussed but have not yet been established (7).

The positive effect of the protein supplementation, applied together with kinesitherapy for 40 days, was also shown unequivocally by the functional study of the quadriceps using myotonometry and the manual muscle test of the knee joint. While the tonus at contraction of the injured leg quadriceps in the control group increased by 28.8 % without reaching that of the uninjured leg, the tonus of this muscle in the experimental group increased by 53.3 % and become equal with the quadriceps tonus at contraction for the uninjured leg.

The higher grade of MMT found in the knee joint of the operated limb in the protein-receiving group compared with that in the controls at the end of experiment following the 40-day rehabilitation program also confirmed the advantages of including a high-protein supplement in the diet in such cases.

CONCLUSIONS

The results clearly suggest the efficaciousness of applied kinesitherapeutic program in competitive soccer players after arthroscopic knee surgery because of a knee injury; and it adequately deals with muscle hypotrophy. The results are considerably better when this rehabilitation program is carried out alongside a supplementation of the diet with protein with high biologic value in a dose of 1.0 g/kg/day for a period of 40 days.

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