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ORIGINAL ARTICLE

Isokinetic strength training program for muscular imbalances in professional soccer players

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Abstract The aim of the study was to investigate the effect of a muscular training program on soccer players' performance of which initially appeared imbalances or deficits. The study was conducte on 68 professional soccer players (age, 24.1±5.7 years; weight, 76.8±5.7 kg; height, 1.82±7 cm) participating in the championship of the first Greek national division over 2 years. During the preparation period, all the players performed an isokinetic test of knee flexors and extensors (60° s^{-1} and 180° s^{-1}). These initial measurements detected muscular imbalances or deficits in 27 players (40%). The 27 players followed a specific isokinetic training program for 2 months, 3 times per week. After completion of the isokinetic training program, the 68 players repeated the isokinetic test. The analysis revealed significant differences between the pre- and post-training measures at both angular velocities in peak torque values, in differences from one limb to the other, and in peak torque ratios for flexors and extensors. Consequently, the application of this specific isokinetic training program can restore imbalances in knee muscle strength efficiently.

Key words Soccer · Isokinetic training · Muscle imbalance · Knee flexors · Knee extensors

Introduction

Soccer is one of the most popular sports and attracts many participants all over the world [1–3]. This participation, however, leads to a considerable number of musculoskeletal injuries [4, 5]. Some of the factors responsible for soccer injuries are contact with an opponent or field conditions, but they may also be related to training, e.g. muscle-strength imbalances or deficits [1, 6]. Sahrmann [7] and, similarly, Caillet [8] defined muscle imbalance as a failure of the agonist-antagonist relationship. The terms balance and imbalance do not refer to equal or unequal torque values, but to the balance between the torque ratios of agonistic and antagonistic muscle groups. Practitioners have often used ipsilateral agonist-antagonist muscle ratios as standards by which to measure the progress of rehabilitation or to assess muscle imbalance [9]. Concentric hamstring-to-quadriceps torque ratios have been studied extensively [10] with reported averages ranging from 0.5 to 0.75.

Similarly, many researchers have supported that bilateral differences (> 15%) in muscular performance (quadriceps and hamstring) detected with isokinetic measures are important predictors of soccer players' injuries and signs of previous injuries and an incomplete rehabilitation program [9, 11, 12]. Since soccer frequently involves one-sided activities such as kicking with one leg, asymmetries in muscle strength between the two legs are possible [11, 13].

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However, weaknesses and muscle imbalances identified by isokinetic testing are almost always associated with a current or previous injury [14].

The first aim of the present study was to detect the possible imbalances in muscular strength in soccer players. The second aim was to investigate the effect of a specific muscle-training program to restore the normal torque ratios of hamstring and quadriceps, reducing bilateral differences.

Subjects and methods

The study enrolled 68 professional soccer players who played in the first Greek national division in the years 2004 (35 players) and 2005 (33 players). Of these, 12 and 11 players, respectively, were newly added to the team at the beginning of the preparation period. All the players were healthy without obvious symptoms or pain during soccer training.

Isokinetic test

During the preparation period, the 68 players performed an isokinetic test of the knee flexor and extensor muscle groups (pre-training measure), to detect possible imbalances or bilateral differences in muscular strength. A Cybex Norm dynamometer (Lumex, Ronkohoma, USA) dynamometer was used for the isokinetic measurements. Procedures were in accordance with ethical standards of the Committee on Human Experimentation at the Department of Physical Educational Sport Science (Democritus University of Thrace) and with the Helsinki Declaration of 1975.

Prior to undergoing the test, each subject performed a 10-min warm-up of cycling and a 5-min warm-up of stretching exercises. The test was performed in a seated position (hip flexion, 110°).

The starting limb was randomly specified to minimize the effects of learning bias. Three submaximal and one maximal repetition of the trial at each speed were performed before each session to prepare the subject for the testing procedure. Testing was performed at low and moderately high angular velocities: 60° s^{-1} and 180° s^{-1}. These angular velocities have been used by many investigators in order to evaluate knee muscular strength of soccer players [13, 15, 16]. A 30-s rest was allowed between tests for all subjects (between the two angular velocities). Following the testing of one leg, there was a 3-min rest and then testing of the other leg began.

Data were recorded during three maximal repetitions of extension and flexion movements at each speed. The best peak torque value for each angular velocity defined the muscular strength. Deficits were defined as a difference in muscular strength between the two legs of at least. The soccer players were divided into two groups (training and control) according to the presence or absence of a muscular imbalance or deficit, respectively. Muscular imbalances refer to the imbalance between the torque ratios of agonistic and antagonistic muscle group.

Isokinetic training program

Players assigned to the training group followed a specific isokinetic training program for 2 months, at a frequency of 3 times per week, to correct the imbalances and deficits. The isokinetic training program included 10 sets (velocity spectrum exercise). The first 5 sets were executed with maximal effort in both flexor and extensor muscle groups, while the last 5 sets were executed maximally only for the weak muscle group based on the initial measurement (Table 1).

Evaluation and data analysis

After completion of the isokinetic training program, the players of the training group and the control players were re-evaluated on the isokinetic test (post-training measure). Repeated-measures analysis of variance was used to test differences between pre- and post-training measures. Data were analyzed using the SPSS PC (Version 8.0, SPSS Inc., Chicago, IL) program for Windows. Statistical significance was set at $p<0.05$.

Results

The study enrolled 68 professional soccer players of mean age 24.1 years (SD=5.7), mean weight 76.8 kg (SD=5.7) and mean height 182 cm (SD=7). According to the pre-training isokinetic test, 27 soccer players (40%) had muscular imbalances or deficits and thus

Table 1 The isokinetic training program

Angular velocity	Sets, n	Repetitions, n	Muscle group
150° s^{-1}	1	15	Extensors and flexors
180° s^{-1}	1	15	Extensors and flexors
210° s^{-1}	1	15	Extensors and flexors
240° s^{-1}	2	15	Extensors and flexors
240° s^{-1}	2	15	Extensors or flexors[a]
210° s^{-1}	1	15	Extensors or flexors[a]
180° s^{-1}	1	15	Extensors or flexors[a]
150° s^{-1}	1	15	Extensors or flexors[a]

[a] Only the muscles with an imbalance or deficit

formed the training group. In this group, mean differences in strengths of muscles between the two sides of the body were 24% (SD=1%) for the knee extensors and 18% (SD=11%) for the knee flexors at the angular velocity of 60° s^{-1}. At the angular velocity of 180° s^{-1}, the mean differences were 23% (SD=12%) for the knee extensors and 20% (SD=13%) for the knee flexors. Differences in flexor to extensor strength ratios were also found. At the 60° s^{-1} angular velocity, the ratio was 52% (SD=21%) for the right leg and 51% (SD=22%) for the left leg; at 180° s^{-1}, it was 57% (SD=18%) for the right leg and 59% (SD=20%) for the left leg.

These 27 players were interviewed by the rehabilitation trainer about any injuries suffered during the last 3 years. The interviews revealed that 13 players had had hamstring strains, 9 had had knee ligament strains (5 anterior cruciate ligament and 4 medial collateral ligament), 3 had had anterior knee pain and 2 had had an adductor strain.

After the 2-month training program, repeated measures analysis of variance showed significant differences between pre- and post-training measures only for the training group (Table 2). Specifically, the training group improved in peak torque values for extensors and flexors of both knees, at both tested angular velocities ($p<0.05$). In addition, significant differences in peak torque ratios of flexors to extensors were found between the pre- and post-training measurements. At the 60° s^{-1} angular velocity, the ratio changed from 0.52 (±21) to 0.66 (±8) for the right leg, and from 0.51 (±22) to 0.65 (±8) for the left leg. At the 180° s^{-1} angular velocity, the ratio changed from 0.57 (±18) to 0.67 (±7) for the right leg, and from 0.59 (±20) to 0.67 (±9) for the left leg. Finally, at the post-training measures, there were no significant differences between the training group (27 players) and the control group (41 players) in peak torque values for knee extensors and flexors at both angular velocities (Table 2).

For the training group, at the post-training measures, the bilateral difference were significantly reduced (Table 3).

Discussion

Some coaches, athletes, medical personnel and strength and conditioning staff believe that injury is often the result of weaknesses in particular muscle groups, which can

Table 2 Peak torque of knee extensors and flexors, for the right and left legs at two angular velocities. Values are mean (SD)

	60° s^{-1}		180° s^{-1}	
	Right leg	Left leg	Right leg	Left leg
Knee extensor strength (Nm)				
Control group				
Baseline	244.7 (25.3)	243.1 (25.9)	161.4 (21.2)	160.9 (19.8)
Study end	245.8 (25.3)	242.7 (24.1)	163.1 (20.2)	161.7 (18.9)
Training group				
Pretraining	232.6 (31.2)	231.8 (31.9)	156.3 (25.3)	154.2 (22.8)
Post-training	246.6 (21.5)*	243.3 (16.8)*	163.6 (13.5)*	162.6 (16.3)*
Knee flexor strength (Nm)				
Control group				
Baseline	166.1 (20.3)	166.5 (21.6)	123.2 (18.3)	123.6 (16.5)
Study end	167.8 (18.4)	169.6 (19.6)	126.1 (16.8)	125.9 (16.3)
Training group				
Pretraining	154.9 (26.1)	156.5 (27.1)	112.7 (19.2)	111.4 (18.4)
Post-training	169.8 (19.4)*	170.7 (19.2)*	129.4 (15.2)*	126.8 (15.7)*

* $p<0.05$, repeated measures ANOVA vs. pretraining value

Table 3 Bilateral differences in muscle strength, before and after isokinetic training, for 27 soccer players. Values are mean (SD)

Angular velocity	Knee extensors		Knee flexors	
	Pretraining	Post-training	Pretraining	Post-training
60° s^{-1}	24 (10)	10 (5)*	18 (11)	7 (7)*
180° s^{-1}	23 (12)	8 (6)*	20 (13)	4 (4)*

* $p<0.01$ vs. pretraining value, repeated measures ANOVA

be detected by isokinetic testing [14]. However, in contrast, weaknesses identified by isokinetic testing, are almost always associated with a current or previous injury [14]. According to Schwellnus [17], many factors may increase the risk of developing acute muscle injuries, such as a recent previous muscle injury [18-20] and past muscle injury [18, 20].

Hagglund et al. [21] referred that, in Denmark and Sweden, 30% and 24% of soccer injuries, respectively, were re-injuries. This is within the range of what has been reported from most studies, where 22%–42% were re-injuries [22–24]. Inadequate rehabilitation and premature return to play after injury have been suggested as risk factors for recurrence of injury [21].

In addition, Schwellnus [17] reported some other factors that increase the risk of developing acute muscle injuries, such as decreased muscle strength (mainly eccentric muscle strength) and muscle imbalance (decreased eccentric (antagonist) to concentric (agonist) muscle strength).

The most effective interventions to reduce the incidence of muscle injuries are those that address known risk factors [20]. The best approach is to identify risk factors for the population of interest and then develop interventions specifically for that population. In practice, most teams are interested in applying an intervention without first studying the injury patterns and risk factors in their own athletes. In this situation, one of the most obvious risk factor to address is a history of a previous injury [19, 20]. The high rate of recurrence for muscle injuries indicates incomplete recovery and may be attributable to inadequate rehabilitation. Therefore, athletes with a history of injuries could be placed on a rehabilitation program to address the involved muscle group [20].

The isokinetic measurement performed in the present study detected many muscle strength imbalances (concentric hamstring-to-quadriceps ratio lower than 0.6), and deficits (bilateral differences >15%).

Specifically, in two years, 27 of 68 soccer players on this team were found to have deficits or imbalances in the knee joint muscles, attributable to an incomplete rehabilitation program after knee injuries. This result is in accordance with a study by Jönhagen and coworkers [25] who found that sprint runners with a history of severe hamstring strains were weaker than uninjured sprinters. Similarly, Ekstrand and Gillquist [26], in a study of 180 senior amateur soccer players, found that non-contact knee injuries occurred in knees with pathological ligamentous laxity due to previous knee injuries.

The 27 soccer players followed the specific isokinetic training program for 2 months with a frequency of 3 times per week in order to correct the imbalances and deficits. The isokinetic training program uses a method of strength training appropriate to promote an optimal neuromuscular response, i.e. a velocity spectrum exercise protocol consisting of 10 sets [27]. The first 5 sets were executed with maximal effort in both flexor and extensor muscle groups, in order to improve the muscle strength, while the last 5 sets were executed maximally only for the weak muscle group (as determined by the initial measurement), in order to restore the muscle imbalances and deficits.

The results showed that there were significant differences between the pre- and post-training measures in peak torque values for knee extensors and flexors at both angular velocities. It is important that these players not only increase the peak torque values but also decrease the variability (standard deviations) in the strength measures. At the post-training test, there was no significant difference between the training group (27 players) and the control group (41 players) in peak torque values for knee extensors and flexors at both angular velocities.

In terms of the effectiveness of the training program in correcting strength deficits and imbalances, the results showed that the isokinetic training program efficiently restored the muscular performance expressed by peak torque. Thus, an isokinetic test is useful for examining possible muscle strength imbalances or bilateral differences in the strength of knee muscle groups. Performance of a specific isokinetic training program could eliminate these strength deficits and imbalances.

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