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Original Article

Does individual-specific strength training have an effect upon knee muscle strength balances? Knee muscle strength balances

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Abstract

Objectives: The purpose of the study was to investigate the effect of 8-week individual-specific strength exercises on knee muscle strength balance. **Methods:** Totally 42 male voluntary amateur soccer players participated in the study. The players were categorized into 3 groups with 14 members in each one; the control group (CG), maximal strength training group (STG) and individual-specific strength training group (ISTG). The players in both STG and ISTG performed strength exercises for lower extremity for 3 days per week for 8 weeks. Dominant (D) and non-dominant (ND) leg concentric extension and concentric flexion of the players were determined by means of isokinetic dynamometer called 'Biodex' at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities. Wilcoxon test was conducted to determine the differences between pre-test and post-test of the groups. **Results:** Dominant and non-dominant leg H/Q ratio was specified to increase in ISTG at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities ($p<0.05$). Although no statistically significant difference was found in terms of bilateral deficit in any groups, BLD was noticed to decrease significantly in dominant and non-dominant legs in ISTG group. **Conclusions:** As a result, it was determined that in STG and ISTG considering the strength deficits of the athletes was to increase the H/Q ratio and reduce BLD, yet the H/Q ratios and BLD yielded a better improvement in ISTG, and thus leading a more effective method in individual training.

Keywords: Soccer, Hamstring-quadriceps Ratio, Bilateral Deficit

Introduction

Strength is an important factor for the basic actions in soccer such as kicking the ball, sprint, turns, jumping and sudden turnaround[1,2]. This strength is especially essential in lower extremity muscles[2,3]. It has been reported in previous studies that knee muscles in soccer have high efficiency upon shooting the ball, passing, jumping, sprint and turnaround[4] and quadriceps muscle is important in jumping, balance and kicking the ball, and hamstring muscle is important in sprint as well as protecting the stability of the knee[3,5]. Hamstring and quadriceps muscle strength are significant components for a better performance, and ratio of these muscles to each other is efficient in determining the risks for sports injuries in advance[6].

As an aggressive and contact-based game, soccer there are several lower-extremity injuries. In lower extremity, injuries of knee (31.8%) are the most frequently encountered one[7,8]. Especially in team sports, hamstring and ACL injuries are frequently encountered, and pose a serious problem. The most important reasons for these injuries are indicated as high BLD and low H/Q ratio.

H/Q ratio is obtained as a result of comparing knee flexors with knee extensors[9,10]. Several related studies have reported that H/Q ratio should be between 0.5 and 0.8, and angular velocity and H/Q ratio increase in parallel with each other[10-11]. While some studies suggest that this ratio is to be between 0.5 and 0.8, others suggest that it should be at %66[12]. Moreover, there are also some certain studies stating that when H/Q ratio was closer to 1.0, the risk for hamstring[12] and ACL injuries decreased[13]. In a similar study, it was mentioned

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that strengthening of quadriceps muscle strength rather than hamstring muscle deteriorated H/Q ratio, decreased co-activation of quadriceps muscle strength with hamstring muscle, and increased the ratio of ACL injuries[14,15].

Another factor that causes the decrease at performance and sports injuries is BLD that occurs due to less use of some areas or parts of the body. Preferring one part of extremity during cyclic or acyclic movements can cause deterioration of strength asymmetry. This is frequently noticed during the use of dominant leg[16]. The previous studies have also reported that BLD is to be below 10%[9,17]. Knapik et al. mentioned that injury possibility of the sportsmen with BLD over 15% was 2.6 times more often than the sportsmen with BLD below 15%[18].

Balancing low hamstring strength that causes both the increase risks for injuries and performance, high BLD and low H/Q ratio have become essential for the sports scientists. In the current literature, there have been several studies investigated such questions as "What kind of training method should be performed in order to provide this muscle balance?" "Are the in-session branch-specific trainings enough to provide this muscle balance?" "Are maximal strength trainings likely to be adequate for improving these strength ratios?" "Which muscle group trainings are possible to be helpful in terms of improving these muscle strength ratios?". Giove, et al. found that high level sport activities in non-ACLs could be achieved with equal or stronger hamstring muscle strength quadriceps. These findings have led to the prevention of ACL injuries based on strengthening hamstring muscles and improving proprioception[19]. In the study conducted by Mjolsnes et al. supported the findings of the study performed[20] by Giove et al.; it was determined that H/Q ratio of soccer players who performed Nordic hamstring exercise increased19. In a similar study, it was revealed that 8-week strength training including leg extension and leg curl movements increased H/Q ratio in basketball, handball and volleyball players[21].

However, the development of muscle strength at the same time as providing muscular strength balance to the athletes is crucial in preventing sports injuries and improving sporty performance. Bearing in mind, the question sought for is that 'Is it possible to maximize hamstring and quadriceps muscle strength with maximal strength training while providing individual strength training and knee muscle strength balances?' In the current study, ISTG was given maximal strength training to increase both quadriceps and hamstring muscle strengths as well as individual strength training for limbs with increased muscle strength to increase H/Q ratio and reduce BLD. The lack of studies in the literature on adult athletes in this type constitutes the authenticity of the current study.

Material and method

Design

The current study was conducted to evaluate the effect of 8-weeks individual strength training on H/Q ratio and BLD in amateur soccer players. Two days before the start of the strength exercises, the soccer players were individually assigned 1-repeat maxima (1-RM) for each exercise. According to the determined 1-RM, each maximal strength training was applied to each athlete. The pyramidal method was used for strength training practice. The 1-RM was renewed after the 4-weeks training program. Measurements were taken from soccer players participating in the study, three days before starting to exercise and three days after 8-weeks exercises. In the study, single-blind method was performed, and only the researcher was aware of the study results and performed training programs.

The participants

Totally 42 voluntary male amateur soccer players who actively play soccer participated in the study. In terms of the control group (CG), age average was 22±1.35 years old, height average was 178.42±5.65 cm, bodyweight average was 71.42±6.92 kg and body mass index (BMI) average was 22.45±1.61 kg/m^2; in terms of strength training group (STG), age average was 23.21±2.29 years old, height average was 179.71±7.66 cm, bodyweight average was 74.07±9.2 kg and BMI average was 22.92±2.39 kg/m^2; and in terms of individual-specific strength training group (ISTG), age average was 23±1.51 years old, height average was 179.5±3.93 cm, bodyweight average was 72.64±5.7 kg and BMI average was 22.54±1.61 kg/m^2. Soccer players were categorized into 3 different groups including 14 individuals in each. The first group was created as the control group (CG), the second group was created as the strength training group (STG), and the third group was created as the individual-specific strength training group (ISTG). The soccer players who participated in the study were regarded to be at least 3-year licensed sportsmen, and having no serious injuries related to knee bond, muscle and joints. The soccer players in the study were informed about the risks of the tests. Prior to the study, all the players were informed, and the consent form was provided to be signed voluntarily. Furthermore, all the players who participated in the study were informed that they could leave the study whenever they wanted without any penalty.

Strength training program

The study covered 8-week training period in the second half of 2015-2016 soccer season. At the beginning of this study period, isokinetic knee strengths of the players were determined, the soccer players were assigned to 3 different groups including 14 each. The first groups was the control group (CG) performing only the training, the second group (STG) performed strength training related to lower extremity for 3 days in a week in addition to the soccer training, and the third group was individual-specific strength training group (ISTG) performing extra exercises related to areas with strength deficiency in addition to the STG program.

The soccer players in the third group performed individual strength trainings evaluating as those with low

Table 1. 8-week strength training program performed by STG and ISTG groups.

Movement	Week/ day	Number of sets	Number of repetition	Load (% of 1-RM)	Resting
a,b,c,d,e,f,g			8	85	
	3	4	6	90	30
			4	95	
			2	80	

Table 2. 8-week strength training program ISTG group performed as extra.

Group	Movement	Week/day	Number of sets	Number of repetition	Load (% of 1-RM)	Resting
HQD	c,g			8	80	
BED	a,e	3	4	6	85	30
BFD	c,g			4	90	
				2	95	

H/Q ratio (LHQ), those with low bilateral flexor strength (LBF) and those with low bilateral extensor ratio (LBE). Two days before the start of the strength exercises, maximum 1 repetition (1-RM) of the soccer players were determined separately for each exercise. Maximal strength training specific to each player was performed according to determined 1-RM. After the strength training program performed for 4 weeks, 1-RM was renewed. As the training model, it was preferred that pyramidal training method in which number of repetition decreased as the load increased, and number of repetition increased as the load decreased. In these sessions, correct performance of the movements were expressed, demonstrated and provided for the soccer players who performed the assigned exercises. The training program included totally 7 movements related to lower extremity. These were the movements of: a) Seated single leg press, b) standing leg adduction, c) seated single leg curl, d) standing leg abduction, e) seated single leg extansion, f) standing calf raises, g) standing single leg curl.

As it is given in Table 1, it can be clearly seen that 8-week strength training program performed by STG and ISTG groups on lower extremities muscles 3 days a week including 7 movements (seated single leg press, standing leg adduction, seated single leg curl, standing leg abduction, seated single leg extension, standing calf raises, standing single leg curl) through pyramidal method between %80 and %95 loads with 4 sets.

As can be seen in Table 2, seated single leg curl and standing single leg curl exercises of the soccer players in group ISTG, whose H/Q rates are low, those with bilateral extensor deficit (BED) who performed seated single leg press and seated single leg extension exercise, those with bilateral flexor deficit (BFD) who performed seated single leg curl and standing single leg curl exercises in addition to the exercise given in Table 1, which performed for 3 days a week through the pyramidal method the between the strength of %80 and %95 4 sets.

Table 3. Weekly training program.

Days of the Week	Training Groups	Training Types
Monday	Study Group	Strength Training
Tuesday	Football Training	Endurance Training
Wednesday	Study Group	Strength Training
Thursday	Football Training	Velocity-technical Training
Friday	Study Groups	Strength Training
Saturday	Football Training	Technical-Tactic Training
Sunday	Football Training	Match

Training program

The study was conducted during the second half of 2015-2016 season. During this period, 3 trainings aiming at the development of motoric properties and technic-tactic improvement were assigned to the soccer players. Furthermore, 1 official match was held every week. Strength exercises performed in the current study included the days without any training. Content and days of the training and days of the strength training performed in the study were presented in Table 3.

According to Table 3, it is evident that the soccer players who performed strength exercises for 3 days a week, while for 3 days they performed 3 soccer traning, on the final day they played a match.

Table 4. The table for isokinetic peak torque (PT) pre-test and post-test differences of dominant and non-dominant leg flexor and extensors.

	CG (n=14)			STG (n=14)			ISTG (n=14)		
(Nm)	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value
D 60°s^{-1} PTQ	205.03±38.82	203.07±56.61	.51	215.83±37.47	227.05±40.17	.14	210.74±28.32	232.94±37.27	**.004***
D 60°s^{-1} PTH	108.79±21.34	122.57±23.47	.056	116.42±19.39	131.7±25.2	**.009***	119.20±15.59	155.77±29.94	**.002***
D 180°s^{-1} PTQ	140.07±24.05	142.42±20.97	.363	140.55±19.54	151.2±24.65	.074	141.02±15.89	160.67±26.0	**.006***
D 180°s^{-1} PTH	81.7±14.19	84.95±14.05	.221	88.63±14.37	99.42±17.35	**.028***	90.47±11.36	115.76±19.58	**.001***
D 300°s^{-1} PTQ	102.73±15.53	105.88±16.46	.638	107.97±17.18	120.32±27.89	.056	107.87±13.33	124.75±19.87	**.004***
D 300°s^{-1} PTH	76.24±14.91	75.85±16.7	.73	78.84±11.07	89.06±16.55	**.011***	81.25±12.45	103.9±18.71	**.003***
ND 60°s^{-1} PTQ	206.2±45.82	211.45±37.46	.117	213.27±34.3	217.21±44.77	.331	212.72±35.32	244.62±43.38	**.006***
ND 60°s^{-1} PTH	110.45±19.46	115.12±21.41	.245	118.53±18.94	130.72±25.18	.074	113.65±16.15	150.07±33.64	**.001***
ND 180°s^{-1} PTQ	133.21±21.53	140.28±21.27	**.044***	137.88±24.67	148.92±23.76	.096	142.1±21.9	160.91±29.16	**.022***
ND 180°s^{-1} PTH	83.68±10.74	85.39±14.19	.551	87.16±14.94	96.24±14.68	**.035***	84.43±10.46	112.34±19.98	**.001***
ND 300°s^{-1} PTQ	102.38±16.51	108.92±14.43	.074	105.11±16.61	117.62±20.75	**.004***	107.59±22.94	126.6±21.54	**.005***
ND 300°s^{-1} PTH	81.85±14.86	79.98±15.13	.414	81.42±13.56	91.02±11.7	**.007***	80.43±9.59	109.33±19.97	**.001***

*PT= peak torque; Q= quadriceps; H= hamstrings; Nm= newton meter; D=dominant; ND=non-dominant. * p<0.05 significant differences between the pre- and post-tests.*

One repetition maximum test (1-RM)

Before the soccer players started strength training, 1-RM test was performed in order to determine individual training weights. So as to determine estimated weight of the players at the beginning of the first 1-RM test, 60% of the bodyweight was considered for the movements related to flexor muscle, and 40% was considered for the movements related to extensor muscle. Each set was performed through the concentric contraction including repetition. The players rested for 1 minute after any movements performed successfully. In the subsequent movement, the test was maintained while increasing the weight. The movements continued until 1-RM unsuccessful attempt made by the players. The last recorded successful movement was saved as 1-RM. One-RM weight was considered for each movement not to be lifted more than one repetition.

Isokinetic strength test

Lower extremity (knee) isokinetic muscle strengths of the players who participated into the study were measured by physiotherapists through Biodex branded isokinetic dynamometer (Biodex 3 Pro Medical System NY, Shirley). Before starting the test, the players, optionally, performed warm-up exercise for 5 minutes at a low tempo on bicycle ergometer or treadmill and stretching exercises for 3-4 minutes on knee joint. After the warm-up, the players were taken to the isokinetic dynamometer one by one for the measurement. Body and leg femurs of the players were stabilized to the chair via tapes from the central part. Furthermore, freeness of the arms was prevented by means of holding the handles on both sides of the chair. Concentric-concentric isokinetic knee strength test including 10 repetitions at 60°s^{-1} and 180°s^{-1}angular velocities, and 15 repetitions at 300°s^{-1} angular velocity was performed. For each angular velocity, the players exercised 3 experiments before the test. The same test was performed on both legs of the players. During the measurements, 3-minute resting break between each of the two legs and 60 second resting break between each angular velocity were taken.

Statistical analysis

The statistical analysis of the data was conducted through SPSS 15 software program, Wilcoxon test as one of the non-parametric tests was used in order to determine PT, H/Q ratios and BLD differences of the players between the pre-test and post-test. In the study, the level of significance was accepted as p<0.05.

Findings

When Table 4 was analyzed, although no significant difference was found between pre-test and post-test hamstring and quadriceps peak torques in dominant leg in the control group, quadriceps peak torque in the post-test increased statistically significant at 180°s^{-1} angular velocity in non-dominant leg (p<0.05). In STG, hamstring peak torque increased significantly at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities in dominant leg, and quadriceps peak torque increased significantly at 300°s^{-1} angular velocity in non-dominant leg in the post-tests (p<0.05). In ISTG, hamstring and quadriceps peak torques at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities in dominant and non-dominant legs was determined to increase as statistically significant in post-tests (p<0.05).

When Table 5 was analyzed, it was found that non-dominant leg H/Q ratio decreased as statistically significant at 300°s^{-1} angular velocity in the control group, and dominant leg H/Q ratio at 60°s^{-1} angular velocity increased as statistically significant in post-test in STG (p<0.05). In ISTG, H/Q ratio

Table 5. The table for dominant and non-dominant leg isokinetic H/Q ratio pre-test and post-test differences.

	CG (n=14)			STG (n=14)			ISTG (n=14)		
(Nm)	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value
D 60°s^{-1} H/Q	53.31±5.88	54.58±6.67	.363	54.47±8.31	58.38±9.24	**.030***	57.11±4.68	66.63±6.13	**.001***
D 180°s^{-1} H/Q	60.38±7.87	60.29±8.42	.73	63.27±7.57	66.12±9.29	.221	64.32±6.01	72.05±5.85	**.003***
D 300°s^{-1} H/Q	74.87±9.04	71.82±11.98	.158	73.96±11.56	76.5±15.42	.300	75.88±12.79	83.8±11.1	**.03***
ND 60°s^{-1} H/Q	54.56±8.3	54.92±7.96	.49	53.26±16.08	60.91±7.74	.055	53.81±5.78	61.05±5.98	**.002***
ND 180°s^{-1} H/Q	63.51±7.52	61.37±9.51	.272	64.9±12.39	65.01±6.42	.414	60.01±7.54	69.33±7.99	**.004***
ND 300°s^{-1} H/Q	80.67±13.3	73.39±10.84	**.026***	78.29±12.45	77.95±8.47	.95	76.51±11.31	87.44±15.14	**.019***

*H/Q= hamstring-quadriceps ratio; D=dominant ND=non-dominant; * p<0.05 significant differences between the pre- and post-tests.*

Table 6. The table for the bilateral pre-test and post-test strength difference.

	CG (n=14)			STG (n=14)			ISTG (n=14)		
(Nm)	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value	Pre-Test	Post-Test	P value
BLD 60°s^{-1} H	8.4±10.96	9.43±9.24	.975	9.76±7.17	12.82±11.52	.331	12.95±15.76	7.45±5.15	.133
BLD 60°s^{-1} Q	10.51±5.72	9.13±7.64	.331	6.47±5.19	12.19±12.74	.069	14.54±16.67	7.38±7.68	.055
BLD 180°s^{-1} H	11.01±8.15	12.7±12.28	.433	7.89±5.63	9.02±7.68	.60	8.09±6.14	5.52±4.52	.103
BLD 180°s^{-1} Q	7.95±8.44	8.66±5.92	.433	7.75±7.65	4.94±5.43	.173	10.4±12.12	8.11±4.64	.778
BLD 300°s^{-1} H	11.69±7.22	11.65±7.21	.683	11.03±9.23	10.77±7.68	.925	8.83±6.85	8.5±3.84	.754
BLD 300°s^{-1} Q	10.82±6.75	8.35±4.04	.140	6.37±5.74	8.83±5.37	.30	12.0±10.12	8.24±6.58	.124

*BLD= bilateral deficit; Q= quadriceps; H= hamstrings; * p<0.05 significant differences between the pre- and post-tests.*

in dominant and non-dominant legs at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities were determined to be increased as statistically significant in post-tests (p<0.05).

When Table 6 was analyzed, no significant difference was determined between BLD pre-test and post-test results at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities in CG, STG, and ISTG. Even though no significant difference was found between BLD pre-test and post-test results of ISTG group, a significant decrease was noticed in post-tests of all angular velocities.

Discussion

The athletes presenting the highest strength they have as much as the weakest of the muscle and muscle group strength they have have proved that inter-muscular strength balance is more important than the current highest strength[22]. This muscle balance is fairly remarkable in bilateral leg quadriceps and hamstring muscles and H/Q ratio in lower extremity. Accurate evaluation and development of muscle strength balances is important in terms of the increase in performance, and thus creating accurate and efficient training programs and for the rehabilitation process during and after injuries caused by muscle strength deficiency of the athletes[23]. The studies to regulate knee muscle strength ratios can be categorized as combined strength exercises related to developing quadriceps and hamstring muscle strengths together, hamstring-based exercises, and investigating the effects of branch-specific trainings. The current study was designed in a more comprehensive way rather than other studies in the literature. The current study included CG in which effects of only branch-specific trainings were investigated, STG including the combined strength exercises related to developing both quadriceps and hamstring muscles together, and ISTG including individual-specific strength exercises as different from the other studies.

In the catogorized groups, 8-week soccer trainings and strength exercises were assigned. When the obtained results were analyzed, it was determined that hamstring and quadriceps peak torque pre-test and post-test results in control group were similar, but there was an increase in hamstring and quadriceps peak torque post-tests of STG and ISTG. This increase occurred mostly in ISTG. Whereas dominant and non-dominant leg H/Q ratio was noticed to have increase in both STG and ISTG at 60°s^{-1}, 180°s^{-1} and 300°s^{-1} angular velocities, the increase in ISTG was determined to be higher as statistically significant when compared to STG in terms of percentage. Although no statistically significant difference was found in terms of BLD in any groups, BLD was noticed to have decreased significantly in dominant and non-dominant legs in ISTG.

It is true that strength trainings develop muscle strength. Some studies indicated that technical tactic training, matches, condition training and all other activities have an effect on strength levels of soccer players positively when

combined with strength training[24,25]. There have also been studies investigating the effect of in-session training and matches upon knee muscle strengths, BLD and H/Q ratio.

For example, in the current study investigating the change in H/Q ratio and BLD after 24-week soccer training program assigned to the Turkish professional soccer players, Eniseler et al. determined that H/Q ratio increased and BLD decreased significantly in the post-test performed at the end of 24 weeks at 60°s^{-1}, 300°s^{-1}, and 500°s^{-1} angular velocities[26]. The findings of the current study are similar to the study conducted by Eniseler, et al[26]. In their study, they determined that there was difference in H/Q ratio and BLD, although the control group performed soccer training only. This could be related to Eniseler et al. administering a 24-week training program regardless of 8-week training. Furthermore, the differences in training content and the number of training sessions weekly due to amateur soccer players in the study in contrast to professional players in Eniseler et al. study, it was also likely that these two studies are incomparable[26].

In the literature, strength exercise programs could make positive contributions to muscle strength balance and functionality providing movement coordination and strength development[27,28]. In the literature, there were also studies conducted supporting this knowledge.

For example, in their study conducted with 34 amateur soccer players, Cihan et al. reported that 12-week leg press exercise for 3 times in a week decreased BLD, which was statistically significant[29].

In their study, Mendiguchia et al. categorized 60 soccer players into two groups through the random method as the control group performing only soccer training and the exercise group performing eccentric hamstring strength, velocity and plyometric trainings for 2 days in a week throughout a 7-week period in addition to soccer training. At the end of 7-week training process, it was noticed that there was a decrease in quadriceps muscle strength and significant increase in hamstring muscle strength of the group performing exercise. Furthermore, it was also determined that H/Q ratio increased in both dominant and non-dominant legs in the post-test together with the increase in muscle strength[30].

In a similar study, Daneshjoo et al. categorized 36 professional soccer players into 3 groups as the control group, the group performing Harmoknee program (including 4 movements as muscle activation, balance, strength and core stability) and the group performing FIFA 11+ program (including 6 movements as strength, balance, muscle control and core stability). Eight week exercise programs for 3 days in a week were performed to FIFA 11+ and Harmoknee groups. In conclusion, it was determined that there was an increase in H/Q ratio of both groups[31].

Another study was conducted related to bilateral strength differences in old individuals to reach the levels of young individuals, and 43 male individuals over 65 years old and 14 male individuals at 20-30 years old were included in the study. The old individuals who participated in the study were categorized into 3 groups. Whereas the first group represented the control group, the second group included the individuals performing balance exercise, and the third group included the individuals performing leg press, leg-extension, calf raise, and foot dorsi-flexor strength exercise. At the end of the study, it was revealed that BLD decreased in groups performing balance and strength exercises, and the group with the most significant development was the one including the individuals performing strength exercise[32].

As for the current study, the exercise program performed by STG (combined exercises related to quadriceps-hamstring-calf muscles) was similar to the programs in aforementioned studies. Although increase in H/Q ratio and decrease in BLD were noticed in aforementioned studies, only peak torque of hamstring and quadriceps muscles increased in the current study. In STG training program, equal strengthening of quadriceps and hamstring muscles in dominant and non-dominant legs caused H/Q ratio and BLD to be maintained at the same level.

It has been known that the imbalance in H/Q ratio is correlated with the weakness of hamstring muscle[33]. Since this ratio was hardly possible to be balanced by means of decreasing the strength of quadriceps muscle, it is recommended that further studies related to increasing hamstring muscle strength be conducted. In the literature, there have been studies on only hamstring-based exercises in order to increase H/Q strength ratio. For example, in their study, Mjolsnes et al. categorized 21 male soccer players into two groups as the ones performing hamstring exercise and the ones performing hamstring curl exercise, and the soccer players performed these exercises for 10 weeks. At the end of the study, it was determined that H/Q ratio of the soccer players performing Nordic hamstring exercise increased, and no change was noticed in H/Q ratio in soccer players performing leg curl exercise[20].

Similarly, Holcomb et al. reported that 12 international female soccer players performed 6-week hamstring-based endurance exercises and thus leading to an increase in the players' H/Q ratio significantly[34].

It has been known that physiologic and psychological properties, weaknesses and strengths of any players are likely to be different from each other. In this sense, an exercise method including individual exercises was performed to regulate H/Q ratio and BLD. Besides, considering that trainers should develop an individualized training program including development of pre-determined technical-tactic abilities, physical properties, weaknesses and strengths of the sportsmen[35]. In the literature, there was only one study including individual exercises to regulate knee strength ratios.

Śliwowski et al. categorized 24 elite juvenile soccer players into two groups as the ones performing 12 strength exercises for lower and upper extremity and the ones performing 2-3 individual-specific strength exercises related to the area for knee muscle strength difference in addition to aforementioned exercises. At the end of the study, Śliwowski et al. determined that there was an increase in H/Q ratio of the players who performed individual specific strength training and there was no significant difference in terms of BLD in both groups in the post-test rather than the pre-

test. In the current study, it was determined that H/Q ratio increased and BLD decreased in ISTG performing individual-specific strength training[36].

Aforementioned studies administered either only hamstring-based exercise program or activated quadriceps and hamstring muscles through equal loads in order to increase H/Q ratio. It has been known that the imbalance in H/Q ratio is correlated with the weakness of hamstring muscle[33]. Considering this, only hamstring-based exercises were administered in order to increase H/Q ratio. However, developing muscle strength along with providing muscle strength in athletes is remarkable in terms of performance. In the current study, exercise program was administered to ISTG aiming at the development of both quadriceps and hamstring muscle strength, and extra hamstring exercises were performed in order to increase in H/Q ratio. When the research results were taken into consideration, it was noticed that although there was an increase ragarding strength in both quadriceps and hamstring muscles in STG and ISTG, H/Q ratio was higher in ISTG who performed extra exercise related to muscles with strength deficiency. Furthermore, although there was no statistically significant difference between pre-test and post-tests of BLD in ISTG, it was determined that there was a decrease in BLD of hamstring and quadriceps muscles below 10%, which was regarded as the critical limit at all angular velocities.

Consequently, it was determined that administering strength exercises related to quadriceps and hamstring muscles was necessary upon considering that providing muscle strength balance in sportsmen as well as developing was remarkable in terms of decreasing the risk for injuries and increasing the performance. Moreover, it was proved that performing individual strength exercises was essential in order to increase H/Q ratio and decrease BLD.

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