Journal of Physical Education and Sport ® (JPES), 11(3), Art 45, pp.291 - 299, 2011
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Corrective effects of different training options on development and maturation of professional motor skills from dominant and non-dominant legs of young soccer players.

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Published online:: September 25, 2011
(Accepted for publication August 28 2011)

Abstract

The purpose of this study is to investigate the effects of the different options of special technical training on development of motor skills in effective performance of dominant and non-dominant legs of young footbolers. 47 volunteer male soccer players (13 years of age) from three soccer teams participated in the study. Young athletes were divided into two experimental (E1 and E2) and one control (C) groups. There were no significant difference between individuals.

Investigation was carried out for 1 year - 3 days per week. The participants were tested three times. Each training session included different training modes of specific corrective exercises. In group E1 the corrective ratio of usage of subdominant/ dominant leg was 4; In group E2 the ratio was 1:1. In the control group all training sessions were conducted in traditional way in which 80-90% of time players used only leading leg as manipulative. Six professional technical skills were subjected to evaluation. Results were processed using the method of analysis of variance and post-hoc Tukeya´s test.

Both versions of specific training ratio of the legs have resulted to a significant advantage in effectiveness of motor performance ($p < 0,05$-$0,001$) in both experimental groups (E1 and E2) over the control (C). This advantage was apparent in a number of qualified sport techniques performed with both legs.
More effective uni- and bilateral formation of the specific soccer skills was demonstrated in experimental group E1, despite a lesser number of corrective training hours during one year of training. In the end of the experiment significant differences between dominant and non dominant legs in experimental and control groups were seen. This fact may indicate that an adolescent have some potential for future maturation of the manipulative skills from non dominant leg in terms of development of more expressive bilateral behavior.

Introduction

It has been shown previously that right-footed athletes make use mainly of their right foot for most unilateral sport skills and in a more definite manner (Geschwind, Galburda, 1985; Zakas, 2006) It has been suggested that leg dominance contributes to poor agility performance and higher risk for injury in soccer players. (Jones, Bampouras, 2010).. The amount of dominance a person experiences is partly congenital, partly a result of practice. Experimental observations show that the performance markedly increases when both feet actively take part in contact with the soccer ball (Donskoj, Zatziorski 1979; Starosta 1990). However because dominance of the lower extremities is present in the majority of the genaral populaton, most soccer players use their dominant limb to kick (McCurdy, Langford, 2005; Lees , Nolan, 1998; Kramer, Balsor, 1990). This unilateral demand may lead to differences in motor ability especially strength and coordination (Haaland, Hoff, 2003; Kearns et al., 2001). This dominance of the lower extremities is not only hindrance fo development of professional skills for a soccer player, but also could be a factor responsible for mechanical overloads and compensatory mechanisms that influence technique of movement and posture (Maupas et al., ,2002). It has been demontrated that sportsmen increase attention to the side of execution when using the nondominant foot (Ford et al., 2005) and this can reduce their performance (Beilock et al., 2002). The non dominant leg demonstrated a lower level of flexibility, strength (Kramer, Balsor, 1990, Rahnama et al., 2004) speed of strike (Barfield et al.,2002) as well as a weaker momentum in action (Barber et al.,1990 and Clark , 2001).

The strength, speed and endurance of the lower limbs significantly develop under the influence of training and this development applies equally to both limbs (Sedano Campo et al., 2011).

Investigation of the bilateral differences between biomechanical indices of legs of footballers and athletes of various other sportsand healthy people brought contradictory results. Some researchers suggest the existence

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of a significant asymmetry which apply particularly to muscle force (McLean and Tumilty 1993; Chin et al., 1994; Ergun et al., 2004; Masuda et al., 2005;). and stretch (Molnar and Alexander 1974; Goslin and Charteris 1979; Wyatt and Edwards 1981). This was not found to be significant by some other authors (Rochongar et al., 1988; Capranica et al., 1992; Brady et al. 1993; Rosene et al. 200; Siqueira 2002; Tutrunen et al. 1996; Masuda et al. 2003; Hoshikawa et al. 2009; Magalhaes et al. 2004; Rahnama et al. 2005; Galazoulas et al. 2005; Chow et al. 2006; Zakas 2006; Spratford et al. 2007; Teixeira, Teixeira, 2008),

On the other side specific behavioral observations of the players during training sessions and competitions, as well as other additional objective measurements suggest that there is a significant difference between the legs when performing various exercises (Starosta 1988; Teixeira et al. 1998-2003; Ljach et al. 2003; Haaland, Hoff, 2003; Witkowski 2007; Gür et al. 2008; Iga et al., 2009; Ljach, Witkowski , 2010).

Leg asymmetry may be caused by local factors rather than being genetically pre-determined. In particular an imbalance of mechanical forces (Ruff & Jones 1981, Steel & Mays 1995) results in development of anatomical and functional asymmetries which increases with age (Steel & Mays 1995, Kearns at al., 2001; Fousekis et al., 2010).

Based on the predominantly mechanical origin of asymmetry of the long bones some sport researchers recommend to train the non-dominant leg for correctional purposes (Hagerman, 2002; Haaland, Hoff, 2003) They demonstrated that specific training of the non-dominant leg improved its manipulative abilities in addition to aiding the development of bilateral motor skills. However this study included only short term specific training of the non-dominant leg (over 8 weeks) and was controlled by a small number of soccer-specific tests. In addition the current literature does not focus on the influence of isolateral vs. bilateral leg training among soccer players at the very beginning of puberty.

Thus our aim was to find out how specific training of the dominant and non-dominant foot may improve on the bilateral technical skills of adolescent footballers. Also, our question would it possible to increase the functional significance of the non-dominant leg on the basis of specific training correction.

Methods

Participants

All subjects were young male soccer players at the age of 13. All of them were from the best Polish sports clubs. All participants completed a physical and anthropometrical examination, with a functional assessment. The training load and degree of involvement in daily exercises of the subjects were documented.

The subjects were divided in three groups. The first experimental group – "E1" was from soccer club Hutnik Krakow (21 participants), the second group "E2" - from Wisla Krakow club (14) and control group – "C" (from Kracovia Krakowclub - 12 participants). The average number of minutes trained per week was recorded, analyzed, and compared between groups. There were no significant difference between the three groups in terms of morphometric data (height and body mass) and sport experience.

Experimental protocol

The dominant limb of each player was determined by the Hoffman method (Hoffman et al., 1998) with kicking task [Parkin et al., 2001]. Using the previously developed reliable and valid motor tests offered by Witkowski & Ljach (2006) we assessed six technical skills (see table 1). These Field tests provide results that are specific to the sport and are therefore more valid than laboratory tests. (Svensson & Drust ,2005).

Table 1. The List of the tested technical skills and associated tests (from Witkowski & Ljach , 2006)

Index	Technical skill tested	№	The Name of test
A	Effectiveness in Dribbling	1.	Dribbling the ball between the uprights with a change of direction
B	Effectiveness in Strikes a ball using the middle internal part of the lifting segment of foot (in air)	2.	Alternate juggling the ball with foot and head
C	Effectiveness in strikes a ball with the internal part of the foot for short passes (by air)	3.	Strikes the ball at a target, distanced at 7 meters from the participant, which uses the internal part of the foot to hit ball (by air)
D	Effectiveness in strike a stationary ball in long passes using the middle internal part of the lifting segment of foot	4.	Strike a stationary ball using internal part of lifting segment of foot to the gate from a long distance of 20 meters
E	Effectiveness in strikes the ball using the internal part of the lifting segment of foot for short passes (on the surface of the sport hall)	5.	Strikes the ball on the surface of the sport hall using the internal part of the foot towards gym benches
F	Effectiveness in Strikes the ball using the external part of lifting segment of foot for short passes on the surface of sport hall	6.	Strikes the ball using the external part of lifting of foot for short passes on the surface of sport hall towards gym benches

In the experimental groups we used the training session to exercise dominant and non dominant lower extremity. The training session were generally carried out 3 times: the first test (Study 1), at the start of year at the beginning of the pre-season period, the second (study 2) - at the end of the season period (in 6 months) and the third at the end of year (Study 3). This approach was necessary to check effectiveness of specific training interventions (Svensson & Drust ,2005). The routines and time of training, summative load as well as the period of exercise in all groups were identical. In group E1 the specific load on the non-dominant leg was 24 minutes in a training session or 80% of the time devoted to this corrected exercise (or 43.2 hours during the year), and training of the dominant leg lasted 6 minutes of the total training session or 20% of the time devoted to this corrected exercise (14.4 hours per year); thus ratio betwen training of dominant and non-dominant leg was 4:1.

In group E2 the specific load on the non-dominant leg was 20 minutes as well as that of the dominant leg (or 57.6 hours per year) – ratio was 1:1.

In the control group (group C) the training sessions were carried out according to the traditional approach in which in the 80-90% of the cases sportsmen used their dominant legs. Thus, during 12 months 144 workouts were organized in sum. The training sessions were organized three times a week and were aimed at improving the six technical skills (see table 1). Before the study, all subjects received a complete explanation of the purpose and measures of the examination and gave their written informed consent. This study was approved by the Ethical Committee of Krakow Academy of Physical Education (Poland).

Data collection and statistical analysis

The standard statistical program "Statistica" was used. The variables were presented with basic statistical characteristics. The normal distribution of the study results was verified through the test of Shapiro-Wilka. The significance of differences between the results of dominant and non-dominant feet was assessed by t- test for unpaired samples. Evaluation of significant differences between the groups was based on Tukey's HSD Post Hoc Test. Results representing group difference between legs were also calculated in percents.

Results

Asymmetry in various technical skills of 13-year football players

Technical skills of the soccer players from all 3 groups (from both legs) over one year experimental protocol (studies I, II and III) are shown in Table. 2. It demonstrates that over the year the asymmetry between the right and left leg in all groups was significantly decreased.

The data indicated that the greatest bilateral similarity occurred in group “E1”, and it was lesser in group “E2” (see Table 2). The mean difference between the dominant and non-dominant legs in group E1 during the first, second and third testing was 26.3, 18, 4 and 16.4%, while in group “E2” this difference was 34.5, 29.0 and 30% correspondingly.

Table 2. The difference (between dominant and non dominant leg in performance of the tests by footbal players belong to E1, E2, and C groups during the experiment (studies I, II, III).

Index	№ of test	№ of study	Δ% Groups E1	E2	C	Index	№ of test	№ of study	Δ% Groups E1	E2	C
A	1	I	5,13*	7,46***	13,53*	D	4	I	65,48***	80,02**	70,95**
		II	7,13**	7,64***	11,35**			II	47,33**	80,45***	74,26***
		III	5,51*	7,41**	9,32**			III	37,87**	82,32***	60,53**
B	2	I	25,37*	37,42**	27,76*	E	5	I	20,17***	28,06***	17,22*
		II	22,1**	27,22*	47,36***			II	17,25**	20,60**	23,78***
		III	17,01*	27,10**	31,09*			III	11,04**	24,88**	16,28 NS
C	3	I	18,60 NS	28,40 NS	10,08 NS	F	6	I	23,06***	25,77**	26,87 NS
		II	-9,8 NS	20,77 NS	32,49*			II	6,54 NS	17,22 NS	19,28 NS
		III	9,58 NS	17,69 NS	21,17 NS			III	17,36*	20,51*	18,47*

Mean difference between the action of gominant and non-dominant leg in % (on the basis of all tests)	I	26,3	34,5	27,7
	II	18,4	29,0	34,8
	III	16,4	30,0	26,1

Δ% The difference (in percentage) between the dominant and non-dominant foot (if $p < 0,05$ - one star, $p < 0,01$ – two stars at $p < 0,001$ – three stars; NS - differences are insignificant)
Note: the difference in favor of the non dominant leg is marked "minus";

In the control group the difference in technical skills between dominant and non dominant leg from the first to third study remained the same.

Table 2 shows how asymmetry manifested itself in relation to selected technical skills. The highest level of asymmetry was demonstrated by striking a stationary ball with the medial aspect of the foot towards the gate from a long distance (see test 4 - the asymmetry in this case was in the range from 37.87% to 82.32%). The lowest level of asymmetry appeared in test 1 - dribbling the ball (about 5.13 -9.32% correspondingly). Moderate level of asymmetry (from 17 to 47.36 %) was noted in test 2, which demonstrated effectiveness in striking the ball with the middle part of the foot, as well as test 5 (from 17.22 to 28.06%) and 6 (from 6.54 to 26.87).

Comparison of the effects of training programs, designed for technical improvement in groups "E1", "E2", and "C"

We evaluated the effect of trainig period on foot asymmetry in regards to the bove mentioned tests. We found that one year of training led to better results in most technical skills performed by both legs of subjects from all groups. The results were most signficant among participants from group "E1". Their non-dominant leg improved on four of the teststests, while their dominant leg progressed only in two tests.

At the end of the training year participants from group "E2" had modest results - their dominant leg improved in two tests (1 and 2) while the non-dominant leg had a progressed in in just one test. This result was relicated among participants, which belong to the control group.

Thus the greatest progress occurred in group "E1", whereas in group "E2" and the Control group progress occurred in a much smaller number of tests (see Table. 3).

The effect of training and level of technical skills at the end of training period was higher in both experimental groups in comparison with the control (see table 4). At the end of the experiment (study III) the participants belonging to group "E1" ware significantly ahead of the control group (in 5 out of 6 tests for non-dominant foot, 3 of them had significant advantage $p < 0,05$-$0,001$) and 4 out of 6 for dominant legs correspondingly (2 of them had significant advantage $p < 0,05$-$0,001$).

Similarly, comparison between group "E2" and the control group "C" showed improved performance in 5 tests out of 6 for the non-dominant leg with only 2 of them with significant advantage ($p < 0,05$) and 1 test out of 6 for the dominant leg with significant advantage ($p < 0,05$) (see Table. 4).

At the same time, players of the control group had no significant advantage on any of the compared tests (see Table 4).

Table 3. The number of tests of technical skills, where sportsmen of groups "E1", "E2", and "C" significantly improved their results over the year-long experiment (This comparison is presented between studies I and II, II and III and I and III)

Comparison of results between studies	Group								
	E1			E2			C		
	Tests carried out by non dominant leg	Tests carried out by dominant leg	Together	Tests carried out by non dominant leg	Tests carried out by dominant leg	Together	Tests carried out by non dominant leg	Tests carried out by dominant leg	Together
Between I and II	1 (test 6)	1 (test 1)	2	1 (test 2)	0	1	1 (test 1)	0	1
Between II and III	1 (test 2)	0	1	0	1 (test 1)	1	0	0	0
Between I iand III	4 (test1; test 2 ; test 4; test 6)	2 (test 1; test 6)	6	1 (test 2)	2 (test 1 ; test 2)	3	1 (test 1)	2 (test 1; test 5)	3

Table 4. Comparison the results of tests which measured various technical skills in groups of soccer players "E1", "E2" and "C"

№	The number of study	Tested leg	The difference in% between the selected groups		
			Between "E1" and "C"	Between "E1" and "E2"	Between "E2" and "C"
1.	I	ND	11,5*** (E1↑)	6,1* (E1↑)	5,8 (E2↑)
		D	7,3** (E1↑)	5,6** (E1↑)	1,9 (E2↑)
	III	ND	10,5*** (E1↑)	5,3** (E1↑)	5,5* (E2↑)
		D	5,4* (E1↑)	1,9 (E1)	3,5 (E2)
2.	I	ND	46,2*** (E1↑)	9,6 (E1)	40,6** (E2↑)
		D	20,4* (E1↑)	3,2 (E1)	17,8 (E2)
	III	ND	36,4*** (E1↑)	17 (E1)	23,4* (E2↑)
		D	23,5** (E1↑)	5,6 (E1)	19,2 (E2)
3.	I	ND	49,0*** (E1↑)	25,8* (E1↑)	31,3* (E2↑)
		D	16,3 (E1)	3,7 (E1)	19,4 (E2)
	III	ND	24,9 (E1)	4,4 (E1)	21,5 (E2)
		D	13,9 (E1)	4,8 (E2)	18 (E2)
4.	I	ND	60,3* (E1↑)	52,3* (E1↑)	16,8 (E2)
		D	18,8 (E1)	22,2 (E2)	36,8* (E2↑)
	III	ND	42,1* (E1↑)	68,1*** (E1↑)	44,8 K
		D	8,9 (E1)	10,9 (E2)	18,9 (E2)
5.	I	ND	12,1 (E1)	0	12,1 (E2)
		D	4,6 (E1)	4,1 (E2)	8,4 (E2)
	III	ND	10,9 (E1)	7,7 (E1)	3,4 (E2)
		D	1,7 (E1)	11,8** (E2↑)	13,3* (E2↑)
6.	I	ND	18,6* (E1↑)	11,1 (E1)	8,5 (E2)
		D	5,7 (E1)	0,4 (E2)	6,1 (E2)
	III	ND	12,1 (E1)	3,7 (E1)	8,8 (E2)
		D	10,9 (E1)	0,2 (E2)	11,1 (E2)

Remarks: Distinctions between the groups are expressed in %. Significant differences - if $p < 0,05$ - one star, with $p < 0,01$ - two at $p < 0,001$ – three stars; if no star(s) - differences are insignificant). Priority of a particular group indicates a reference to the name of the group (with arrow in case if the difference is significant)

This clearly demonstrates that players from group E1 were significantly ahead of players from Group "E2" in their ability of dribbling with the non-dominant leg as well as accurate strike by non dominant leg using the middle internal part of the lifting segment of foot. In turn, group "E2" had a better score for dominant leg tests (test 5 - $p < 0,05$), than group "E1", in striking the ball using the internal part of the sloping segment of foot. We did not find significant difference in motor skills in either leg when testing short pass of the ball using the external part of slope segment of the foot.

It is interesting that in a number of tests the differences between dominant and non dominant leg in all groups of players even after the one-year technical preparation remained statistically significant.

Discussion

Asymmetrical behavior of the lower limbs in soccer was addressed in numerous investigations and was found to reflect natural functional differences between the lower extremities (Voutselas et al., 2007, Gur et al., 1999, Fousekis et al., 2010; Sannicandro et al., 2011) Significant bilateral differences in number of field tests were found by Jones & Bampouras, (2010), Fousekis et al, (2010) when comparing the strength of dominant and nondominant limbs for all strength measures. On the other side McElveen and coworkers (2010) did not find significant differences between dominant and non dominant leg for jump height in young healthy untrained people Leg asymmetry can be treated as significant etiological factors for soccer injury (Poulmedis, 1988, Ekstrand and Gillquist, 1983; Devan et al., 2004) as well as reduce bilateral professional abilities (Haaland & Hoff , 2003, Fousekis et al., 2010).). It is also well known that long period of soccer training decreases the level of asymmetry, in this case athletes improved their balance. (Voutselas et al., 2007; Gur et al., 1999). Hageman and coworkers (1988) after long period of training found no significant differences in the torque values between dominant and non dominant legs Using trivial method of training of professional runners the investigators found small differences of the kinematic force between feet (Kong et al., 2011). After relatively shot period of corrective training Agre & Baxter (1987) found no significant differences between the dominant and nondominant legs in flexibility and muscle strength. Because asymmetry often appears when the limbs are

asymmetrically loaded we suggests correction of this asymmetry, using specific exercises geared towards development of non-dominant leg. Our study verified that 13 year old soccer players were initially asymmetric in manipulations with their lower extremities. However, this asymmetry was mostly reduced after corrective training when compared to the control. This indicated a positive effect of specific non-dominant leg training in groups "E1" and "E2". Similar effect was demonstrated by Norwegian researchers whose coaching intervention of the non-dominant leg lasted 8 weeks. They showed that training the non-dominant leg significantly increased its motor coordination abilities. In addition they demonstrated significant improvement in the tests performed by the dominant side (Haaland & Hoff , 2003). Starosta in 1990 discovered a similar pattern from athletes of various sports. He explains this phenomenon through a positive transfer of motor skills from action of one limb of the body to another.

Different version of unilateral and bilateral training of soccer players leads to decrease in leg asymmetry. In 2007 Witkowski used the training loading of legs in proportion of 75% (for the dominant) and 25% (for non dominant). A year later, Gür and coworkers (2008) tested adolescent soccer players. Both researchers found a greater similarity of results from both feet, demonstrated by the subjects of the experimental group compared with control. However Teixeira and coworkers (2003) using other version of bilateral training of young soccer players did not report such success. This contradiction in literature may be due to imbalance of muscle force from dominant and non dominant legs, which can be highly individual especially in young persons. The results of our own studies indicate that workout with ratio 4:1 used in the "E1" group (80% of the time was aimed to improving the motor skills of the non-dominant leg, and 20% for the dominant) was more effective than the training routine used in group "E2" (where 50% of the training time was devoted to the dominant and 50% to the non-dominant leg. It has been stated that it is very difficult to maximally reduce leg asymmetry especially when force is concerned in a short period of time (Witkowski , 2007).

In our study even ordinary training sessions witch promoted activities of the dominant leg increased performance of the non-dominant leg. How does this occur? We think that functional differences between legs are probably related to the contribution of each limb in carrying out the specific socceer tasks where non dominant leg usually performers more supportive actions rather than manipulative. Soccer especially requires different loads to the lower limbs as the player uses separately one leg to kick and the other one to jump and landing (Sannicandro et al., 2009);

It explains why the left leg is heavier (Latimer, Lowrance 1965; Singh 1970) and left femur often is stronger, than the right.(Macho (1991) Some researchers also demonstrated the patterns in favor of development of bone of the non dominant leg. For example, finding by McClanahan and co-workers (2002) and Nazarian and coworkers (2010) showed that bone density values of the non-dominant leg of soccer players were significantly higher than their dominant leg, but there were no significant differences between dominant and non-dominant legs of non-athlete subjects. The authors explained their finding by more often usage the non-dominant leg for take off and landing actions and in supporting the body with the non-dominant leg while the dominant is used for shooting. Such activities may stimulate development of long bone tissue and increase the body density of the non-dominant leg. Perhaps, specific and intensive training of the non-dominant leg in "E1" group changed the state of appropriate neural centers (Bernstain, 1967; Enoka, 1994), as well as alternates the mechanical and elastic properties of the muscles (Enoka, 1994) and according to Smith (Schmidt, Lee, 1999) may activated the generalized motor program, which increased manipulative abilities of both legs.

It has to be noted that the differences between dominant and non dominant leg in all groups of players even after the one-year technical preparation remained statistically significant. This fact may suggest that the young players still remained unrealized reserves to improve the basic elements of playing technique of non-dominant leg. On the other side this fact means that bilateral relationship between dominant and non dominant extremities is very conservative thing and even 1 year of training probably is not enough time to completely change this pattern Summarizing the collected material we conclude that the most effective technical improvement of motor dexterity of the non-dominant leg of young players was in the first experimental group ("E1" and less effective in the second experimental "E2" and control "C'' groups.

Conclusions

1. During 12 months of the experiment the functional differences between dominant and non dominant leg in the identical tests progressively decreased. This decrease was demonstrated in both experimental and in control groups, however, experimental groups demonstrated a greater reduction in leg asymmetry.
2 The greatest effectiveness in terms of improvement of the technical skills demonstrated the dominant leg
3 The minimal level of functional asymmetry was illustrated in the first experimental group with training load 80/20 % (correspondingly for the left and right legs).
4 Young players even after one year of training remain unrealized reserves to improve the basic elements of playing technique of non-dominant leg

Potential Conflict of Interest
No potential conflict of interest relevant to this article was reported.
Sources of Funding
There were no external funding sources for this study.
Study Association
This study is not associated with any post-graduation program.

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