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Functional asymmetry of the lower limbs in young soccer players

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Abstract
Introduction. **The authors attempt to examine whether functional differences between the legs in soccer players are similar in different motor tests, and whether possible weaker laterality in soccer players could be the effect of the higher fitness level of their left legs, or the lower fitness level of their right legs.** Aim of Study. **The aim of the study was to determine the scope of differences between the results of motor coordination tests performed with the right leg and the left leg by boys playing soccer and non-training controls.** Materials and Methods. **52 soccer training boys and 25 non-training controls volunteered to participate in the experiment. Motor coordination tests of the left and the right legs were performed by participants in order to assess static balance, rate of movements, dynamic endurance, and kinesthetic differentiation.** Results. **The greatest differences between the training and non-training boys were found in dynamic endurance (left leg, $p < 0.001$; right leg, $p < 0.01$). Coaches' high assessments of players were based on good results of the balance test of the left leg. The differences between the left and the right legs were smaller in the soccer players than in non-training boys, particularly when the results of the left legs were better.** Conclusions. **In both groups under study the functional asymmetry between the right and the left legs in the static balance and dynamic endurance tests exceeded 20%, which may contribute to possible sport injuries. The soccer players' static balance test results indicate the presence of training-induced bilateral transfer of balance ability of the legs.**

KEYWORDS: exercise test, children's sports, physical activity.

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What is already known on this topic?
One of reasons of the low effectiveness of commonly available smoking quitting methods is the fact that the causes of nicotine addiction are still unclear. Another adverse factor affecting tobacco addiction is the ever faster lifestyle, increasing stress and limited time for relaxation, healthy eating and regular physical activity. These are all hindrances to effective smoking cessation

Introduction

The phenomenon of footedness has been widely discussed by various authors, and the impact of physical activity on limb laterality requires further research. Soccer players, coaches, and fans want to know why particular players most often use their dominant leg while shooting at a goal, although being technically well-trained to use both legs to perform any task. Soccer players may show some concern about the inaccuracy and weakness of shots and passes performed with the non-dominant leg. In fact, players' advanced skills to use both legs in performing technical tasks in soccer is often decisive for the match outcome. The above issues are related to two research area. The first one is functional lateralization observed in multiple human motor activities and manifested by the motor dominance of one limb over the other. The other one are motor coordination abilities such as accuracy, speed, and economy of movements. In the course of human development lateralization is subject to change. Gabbard revealed that the laterality of the legs was not yet determined in 50% of 4-year-old children [1, 2]. The relatively stable lateralization appears at the age of 6-8 years, and only environmental factors such as intensive physical activity, or an injury of the dominant leg, can lead to considerable changes.

The lateralization of the legs can be determined by simple fitness tests such as kicking a ball at a target, hopping over an obstacle, or the so-called "putting out the fire" test, or – in the case of older participants – by the Waterloo Footedness Questionnaire [3]. Soccer is a sport in which almost all movements are performed asymmetrically, i.e. with one side of the body. While training soccer-specific actions such as dribbling or shooting, players exercise multiple repeated movements with their dominant and non-dominant legs. This complies with the principle of using versatile training at all training stages. The ability to use both legs effectively is thus extremely useful in soccer. Does versatile training decrease the degree of lateralization of the legs? Solin [4] demonstrated the phenomenon of "logical lateralization" in which symmetric exercises do induce changes in the primary model of lateralization in individual sports. For example, weight lifters (symmetric sport) display a higher degree of ambidexterity (both in their hands, and feet) than wrestlers (asymmetric sport).

There have been multiple studies focusing on effects of sport training on the type and the volume of changes in morphological and functional asymmetry. Authors studying the issue of asymmetry include Olex-Zarychta [5, 6], Wieczorek [7, 8]. An interesting research question related to footedness in sport is assessment of the impact of the degree of functional asymmetry of the limbs on the incidence of sport injuries [9-13]. It has been confirmed, for example, that a 10-15% difference in muscle strength of the lower limbs may contribute to the incidence of injuries in athletes [14]. The differences in the degree of lateralization between young soccer players and non-playing individuals have not been quantitatively assessed. The precise determinants of these differences remain unknown as well as questions about differences in laterality in different motor skills. We do not know either whether weaker lateralization in soccer players can be the result of a higher motor fitness level of the left leg, or a lower fitness level of the right leg, in comparison with non-training individuals.

The present study attempts to determine the size and character of differences between results of motor coordination tests performed with the left and right legs. While handedness has been widely described, footedness still requires further research. There is a strong need to develop studies on footedness that can be effectively implemented in sport and in daily professional and non-professional life. The present study is one such contribution.

Materials and Methods

Participants

Participants in the study included 52 soccer training boys (T group), (mean age 12.3 ± 0.52 years, body height 154.3 ± 7.4 cm, body mass 42.4 ± 7.0 kg), and 25 non-training controls (NT group), (mean age 12.4 ± ± 0.36 years, body height 156.3 ± 9.8 cm, body mass 48.4 ± 13.4 kg).The players attended a sports middle school, and represented the highest sport level in their age category. They had begun soccer training at the age of 5.5 years, and trained soccer every day, from 495 to 540 min per week. The non-players took part in regular 45-min PE classes, three times a week. The study was approved by the Ethics and Standards of Conduct Committee. The parents of participating students provided written informed consent. The Mann-Whitney U test results did not reveal statistically significant differences between the T and NT groups in terms of participants' body height, body mass, and BMI. Both groups can be regarded as similar in body build, and thus properly selected for the study.

Testing procedures

The study tested the usability of authors' own new apparatus for measuring the motor coordination of the legs [15, 16]. The participants performed motor coordination tests with the right, and the left legs. Four simple and commonly used tests that assessed motor coordination components were selected for the study. The comparison between the test results of the left legs, and the right legs allowed the assessment of the degree of lateralization.

Static balance (SB). In soccer, static balance is crucial while playing the ball with the opponent's interference, struggling to gain control of the ball, heading the ball in midair, or performing volley kicks or feints. The static balance test consists of maintaining body balance while standing on one foot for the longest time possible. The test result is the time (in seconds) during which a participant maintains balance, i.e. does not touch anything with his lifted foot (maximal score is 60 s).

Rate of movements (RM). The movement rate is measured by recording the maximal number of movements performed by a given muscle group in a specified time. It is manifested by a player's ability to perform quick feints, and shots. The rate of movements test consists of moving one's foot over a 15-cm-high bar within 20 sec. The participant sits on the chair. A cycle consists of moving the foot over the bar, touching the ground, and returning the foot to its original position. The player's score is the number of cycles completed within 20 seconds.

Dynamic endurance (DE). Dynamic endurance combines motor coordination abilities with physiological exercise endurance. The dynamic endurance of the legs test consists of performing the maximal number of one-foot leaps sideways over a line within 20 s.

Kinesthetic differentiation (KD). Kinesthetic differentiation is the ability to use appropriate force required to perform a given motor task through accurate perception of strength as well as temporal and spatial parameters of movement. Kinesthetic differentiation plays a crucial role in developing the so-called "sensing of movement". Soccer players display their kinesthetic differentiation skills by executing accurate passes, interceptions, and shots. During the kinesthetic differentiation test the participant sits on a chair holding a light carbon fiber tube (10 mm in outside diameter) between his big toe and second toe. Then he tries to insert the tube into a number of holes (11 mm in inside diameter) on the apparatus in a specified order, in the shortest time possible.

Functional asymmetry. Functional asymmetry of the limbs was assessed with the use of handedness tests (reach-up test, "grab your nose and ear", "Which hand do you write with?"); and footedness tests (putting out "fire" by stomping, kicking the ball, crossing one's legs, taking a long stride over an obstacle). The test results made it possible to categorize participants' arms, and legs laterality into three types: right-sidedness, i.e. dominance of the right arm and the right leg; left-sidedness, i.e. dominance of the left arm and the left leg; and cross-laterality, i.e. dominance of the right arm and the left leg, or dominance of the left arm and the right leg [17].

Coaches' assessment. The coaches also made their subjective assessments of the players, and ranked them according to their accuracy of passes, playing technique, motor skills, tactical play, and volitional traits. Each player was assigned a score from 1 to 52 points.

Body build characteristics. The anthropometric measurements included participants' body mass, body height, length, and width of the legs, and indices such as foot length (foot length/body height)*100, thigh length (thigh length/body height)*100, lower leg length (lower leg length/body height)*100, thigh girth (thigh girth/thigh length)*100, and lower leg girth (lower leg girth/lower leg length)*100.

Statistical analysis. The following tests were used in statistical analysis: descriptive statistics, and normal distribution test (Shapiro-Wilk test), Mann-Whitney U test, and Spearman's rank correlation coefficient.

Results

Motor coordination of the legs

The results of the static balance test did not reveal any statistically significant differences between the soccer players and controls. The non-training boys maintained body balance on the right (16.7 s) and the left leg (22.9 s) for a shorter time than the soccer players (Table 1). The greatest differences were noted between the mean results of the rate of movements ($p < 0.01$), and the rate of dynamic endurance tests ($p < 0.001$). In both tests better results were obtained by the soccer players: 26.5 cycles for the right leg, and 24.4 cycles for the left leg. They performed more leaps over the line within 20 s on the right leg (31.6 cycles) and on the left leg

Table 1. Results of motor coordination tests (mean ± SD)

Motor coordination tests	left leg		right leg	
	T	NT	T	NT
SB	27.4 ± 19.9	22.9 ± 19.4	21.8 ± 19.0	16.7 ± 20.8
RM	24.4* ± 2.0	22.9 ± 2.9	26.5** ± 2.0	24.3 ± 3.4
DE	30.4*** ± 3.7	25.9 ± 3.7	31.6** ± 4.1	28.5 ± 3.8
KD	24.1* ± 9.3	28.4 ± 10.2	24.0 ± 9.0	28.2 ± 12.5

Note: Significant differences between the left leg (T/NT) and the right leg (T/NT), *p < 0.05, **p < 0.01, ***p < 0.001; T = training group, NT = non-training group, SB = static balance (s), RM = rate of movements (cycles), DE = dynamic endurance (cycles), KD = kinesthetic differentiation (s).

(30.4 cycles) than their non-training counterparts. The kinesthetic differentiation test results revealed a statistically significant difference ($p < 0.05$) between the two groups: the soccer players performed the test on the left leg faster (0:24.1 s) than the controls.

Leg and arm dominance

The analysis of limb dominance did not reveal statistically significant differences between the groups in terms of their limb preference. Most participants in both groups preferred their right extremities. Participants with left- and cross-dominance were far fewer (Table 2). The laterality type was correlated with the results of motor coordination tests only in two cases: handedness and movement rate of the left leg in the T group ($r = 0.29$, $p = 0.041$) – left-handed participants performed the test better; handedness and static balance of the right leg in the NT group ($r = 0.42$, $p = 0.034$), left-handed participants performed the test better. Interestingly, the test results were often inconsistent with footedness, i.e. the dominant leg attained worse results that the non--dominant leg (Table 2). The highest inconsistency of functional dominance was noted in the static balance test results in both groups. The highest consistency was found in the test results of leg movement rate and dynamic endurance. The percentage of consistency and inconsistency was equally distributed in the kinesthetic differentiation test. The difference between training, and non-training participants was determined by a higher inconsistency in the results of the rate of movements test in the non-training controls.

Coaches' assessment (CoA)

The correlation analysis of five coaches' assessments with results of tests of four motor abilities showed only one significant correlation between a coach's high assessment of a player's motor abilities and low static balance of the right leg ($r = 0.29$, $p = 0.049$). The total result of five coaches' assessments was correlated with the static balance of the left leg. The better coach's assessment was correlated with the better static balance of the left leg ($r = 0.34$, $p = 0.019$). The two results confirmed each other. The static balance of the left leg is important during kicking the ball with the right leg as the left leg supports the player's body balance during kicking.

Body build characteristics

The analysis also aimed at finding correlations between participants' test results, and body build characteristics of the legs. It revealed numerous statistically significant correlations in all coordination traits. The strongest correlations ($p < 0.001$) were found only among the soccer players in dynamic endurance. No motor coordination test results were correlated with players'

Table 2. Types of functional laterality: the number of boys and their arm/leg dominance profile and consistency or inconsistency of the dominant leg with better test results

Dominance		Consistency		SB % n	RM % n	DE % n	KD % n
Training group							
One-side	Right-right 46	Left-footed	Consistent	2 1	4 2	7 4	4 2
	Left-left 3		Inconsistent	6 3	4 2	2 1	4 2
Cross	Right-left 1	Right-footed	Consistent	32 17	88 46	75 39	43 22
	Left-right 2		Inconsistent	60 31	4 2	16 8	49 26
Non-training group							
One-side	Right-right 21	Left-footed	Consistent	0 0	0 0	5 1	0 0
	Left-left 1		Inconsistent	4 1	4 1	0 0	4 1
Cross	Right-left 0	Right-footed	Consistent	42 10	83 21	95 24	48 12
	Left-right 3		Inconsistent	54 14	13 3	0 0	48 2

Note: SB = static balance, RM = rate of movements, DE = dynamic endurance, KD = kinesthetic differentiation.

body mass, body height, or BMI. The strong correlations show that soccer players with long lower legs (absolute length, and relative to body height) display lower dynamic endurance, and that soccer players with long, and wide feet, and longer lower leg girth scored higher on the dynamic endurance test.

Differences in test results between the right and the left legs
Interesting differences were noted between test results of the right, and the left legs. They indicate the direction, and strength of lateralization in particular motor coordination tests. The absolute differences between the test results of the legs were calculated by dividing the legs into more and less fit (rather than into right and left). Then, the absolute difference was calculated into the percent difference between the less and more fit legs. Following Fredericson [14] differences higher than 10-15% may indicate hazards of sport injuries. Such large differences were found in static balance and kinesthetic differentiation tests.

In the static balance test the T group featured better left leg results, while in the NT group the better results of the left legs, and the better results of the right legs, were distributed nearly equally (Figure 1). In the rate of movements tests better results were nearly always attained by the right legs, in particular by the soccer players (Figure 2). In the soccer players a large difference indicated a better result of the right leg. The dynamic endurance test revealed small differences between the left and right legs. In the NT group better results were attained with the right legs (Figure 3), while in the T group, greater differences were noted with better results of the right legs. In the kinesthetic differentiation test the better results of the left legs and the better results of the right legs were equally distributed (Figure 4). These results show that the players mastered effectively ambidextrous kinesthetic differentiation – a key ability of technical precision.
Out of eight arithmetic means of differences in each group only two (SB, and RM with better results of the

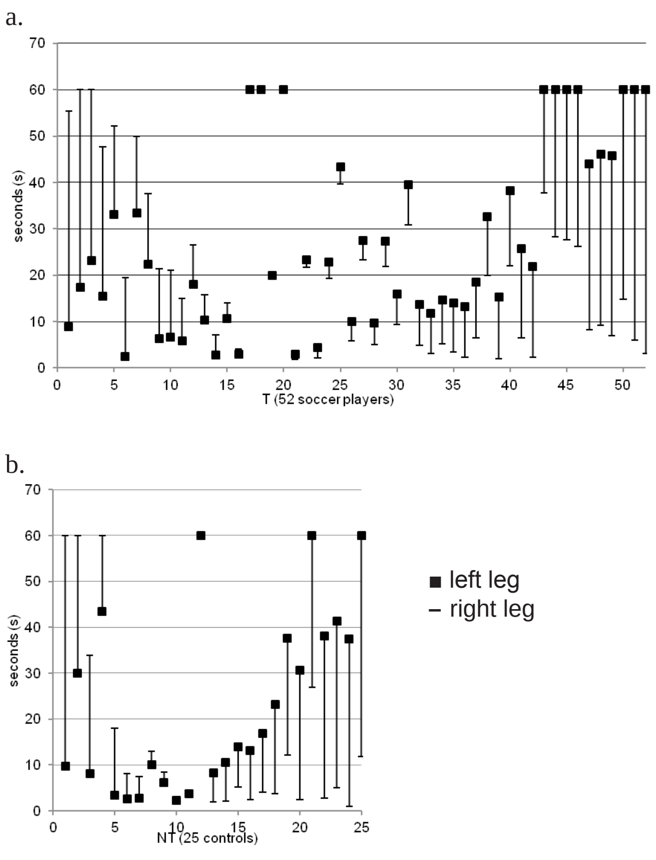

Figure 1. Static balance – differences in test results between the left legs and the right legs in all subjects T (a.) and NT (b.), from the better right leg results to the better left leg results; T = training group, NT = non-training group

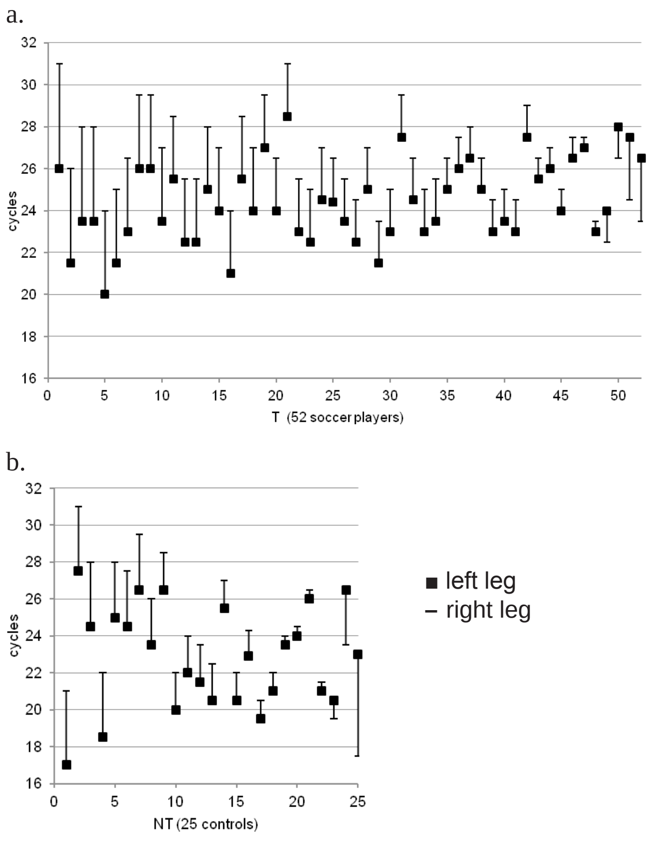

Figure 2. Rate of movements – differences in test results between the left legs and the right legs in all subjects T (a.) and NT (b.), from the better right leg results to the better left leg results; T = training group, NT = non-training group

right legs) generated bigger differences in the T group than in the NT group. This is an indication of a more frequent, smaller left/right side differentiation among soccer players compared with non-training individuals. The four diagrams (Figures 1-4) indicate more frequent small left/right differences in the SB, DE, and KD tests in the T group as compared with non-training individuals. Moreover, it was also noted that the scopes of left/right differences were correlated with respective motor coordination test results, in the T group, in each motor coordination component (from $p < 0.05$ to $p < 0.0001$), and more seldom in the NT group (from $p < 0.05$ to $p < 0.001$). This indicates that in tests in which the left legs attain better results the differences are smaller; however, when the right legs attain better results, the differences are bigger.

The question remains whether there are other determinants of left/right side differences? In the static balance test the big differences are due to good results of more fit legs (not because of worse results of less fit legs), while the less fit legs attain usually similar results. In the rate of movements test, bigger differences can be found in the case of better results of both legs; however, this tendency is not strong. In the dynamic endurance tests the differences are significant when the right leg attains better results. These differences are usually between the better results of the right leg, and similar to other results of the left leg. Finally, the kinesthetic differentiation test showed that more fit legs do attain similar test results. Big differences are due to significantly worse results of the less fit legs. The left/right side differences (numerical values) between motor coordination test results are correlated with some of the examined characteristics (Table 3). The strongest correlation with the left/right side differences in soccer players was found with the left foot width; in the KD test the wide left feet in the T group were less fit than the wide right feet. In the KD test the long thighs, i.e. more fit right legs, generated negative differences. In the DE test in the T group the wide right foot, and the long feet generated big

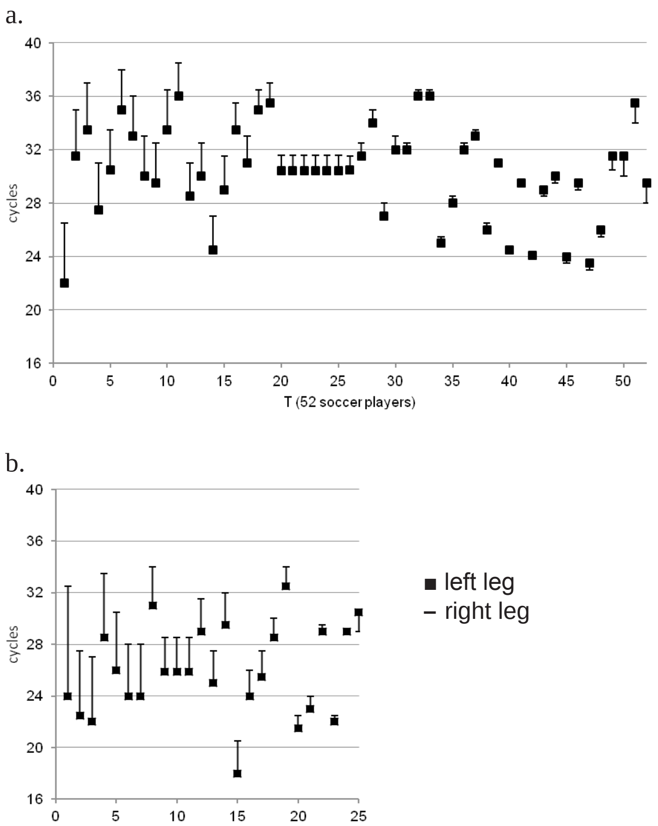

Figure 3. Dynamic endurance – differences in test results between the left legs and the right legs in all subjects T (a.) and NT (b.), from the better right leg results to the better left leg results; T = training group, NT = non-training group

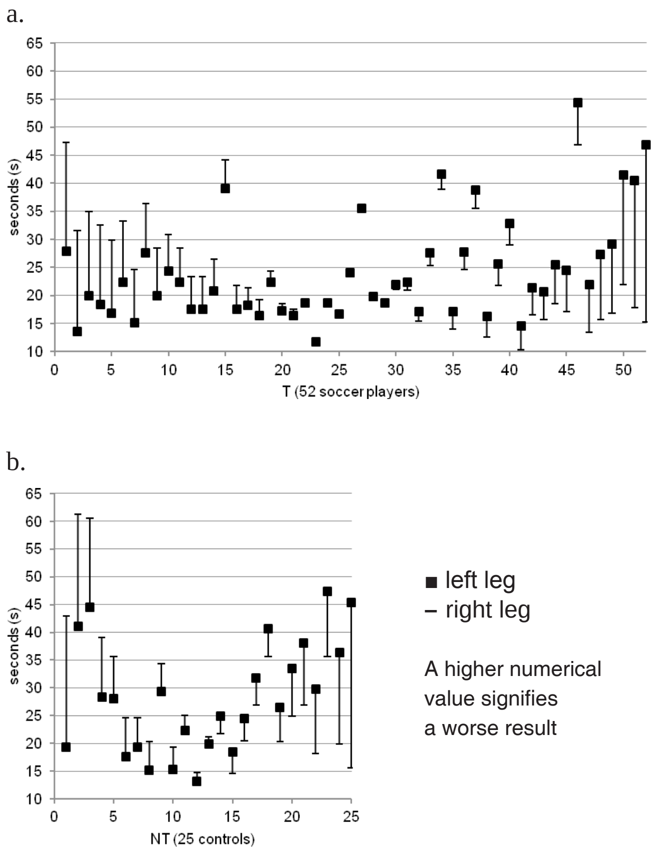

Figure 4. Kinesthetic differentiation – differences in test results between the left legs and the right legs in all subjects T (a.) and NT (b.), from the better left leg results to the better right leg results; T = training group, NT = non-training group

Table 3. Statistically significant correlations between left/right side motor coordination components with other characteristics

Left/right side correlating difference	The other correlating difference	Spearman's rho
T GROUP SB	CoA of passing accuracy	0.35*
	CoA of technical play	0.31*
	CoA of volitional traits	0.37*
T GROUP RM	CoA of motor abilities	–0.30*
T GROUP RM – non-significant footedness 0.28* difference, numerical value of the difference regardless of better results of the left or the right leg		
T GROUP DE	Body height	0.31*
	Right foot width	0.35*
	Right foot length	0.38*
	Left foot length	0.35*
T GROUP KD	CoA of passing accuracy	0.32*
	CoA of technical play	0.34*
	Right thigh length	–0.32*
	Left thigh length	–0.32*
	Left foot width	–0.43**
NT GROUP SB	Body height	–0.51*

Note: SB = static balance (s), RM = rate of movements (cycles), DE = dynamic endurance (cycles), KD = kinesthetic differentiation (s); *p < 0.05, **p < 0.01, ***p < 0.001.

differences, i.e. better results for the right leg. Also in the same test a tall body indicated greater differences, i.e. more fit right legs. The left-footed players displayed greater differences in the RM test. In the NT group, taller participants featured greater differences, i.e. better results for the left legs in the SB test.

The coaches' assessment results were significantly correlated with the left/right side differences in SB, RM, and KD. The better coach's assessment of passing accuracy, technical play, motor abilities, and volitional traits, the better the player's left leg balance. In the KD test good coach's assessment of passing accuracy, and technical play was correlated with a wider differentiation of the right leg. In the RM test players with high levels of motor abilities displayed big left/right side differences.

Discussion

The advantage of soccer training boys over their non-training counterparts in terms of motor coordination skills of their legs was foreseeable, but what is interesting, is that the smallest differences between the two groups were noted in static balance, and the biggest in dynamic endurance. The dynamic endurance test does not merely assess coordination but also strength (one-foot jumps), and strength endurance (number of jumps within 20 sec). Perhaps, it was the particular difficulty of this test that demonstrated differences between the boys from both groups. These results confirm the usability of the dynamic endurance test. The soccer players' balance test results deserve particular consideration. The test revealed a significant advantage of the left leg, and a definite distinction between the left leg supporting body balance, and the dominant right leg in performing shots at goal, and accurate passes. This can be explained by the possible emergence of a bilateral transfer associated with the expansion of nerve fields in motor habit development. The mastery of a skill which is usually performed with the dominant extremity is connected with stimulation of motor nerve centers in the opposite cerebral hemisphere. Haaland confirmed an improvement in the function of both the dominant, and the non-dominant legs in soccer players attending an 8-week training program loading the non-dominant leg [18]. The development of body balance is important to health, and it prevents, for example, injuries of the ankle joint [19, 20]. It should also be kept in mind that the age of 11-13 years is a period of stagnation or even regression of balance maintaining ability [21]. The importance of the left leg as the balance for the proper technique of the right leg has been stressed by coaches, although they have been unaware of relationships between their assessments and players' body balance.

Although there were very few left-handed participants, the left-handed soccer players performed the rate of movements test better with their left legs than the right-handed players. This interesting observation should be verified on a larger sample with the same laterality pattern. If it is confirmed, then left-handed and left-footed soccer players will turn out to be very useful for any team, not only in terms of game tactics, but also as players with high levels of motor fitness.

The study of relationships between coach's assessment of players, and test results leads to the following observation: coach's assessments are less correlated with motor coordination test results, and more correlated with differences between the results of the right, and the left legs, i.e. strength of laterality. This indicates the practical significance of footedness in soccer.

Anthropometric characteristics of the legs were, in particular, correlated – in soccer players and non-training controls – with motor coordination abilities. The strongest correlations were noted with the soccer players' dynamic endurance. It appears that a player with high dynamic endurance is one with shorter, and more muscular lower legs, and with bigger feet. This correlation indicated a great contribution of muscle strength to this motor ability. The left/right side differences in dynamic endurance and kinesthetic differentiation are related to the build of the legs. The observed left/right side differences indicated a smaller degree of laterality in the soccer players. The examination of these differences can yield more information than the analysis of motor coordination test results. The big differences were associated with good rate of movements and dynamic endurance test results of the right legs. This means that soccer preparation should involve more training of the left leg. Also in the static balance test better results should be attained by the left leg; however, this was not the case with all the players under study. Static balance, therefore, should be also a component trained with the left leg.

Conclusion

The inconsistency of the results of the functional asymmetry tests with the results of motor coordination tests (Table 2) is interesting. It confirms the informative value of the tests in the present study, and the usability of the authors' own testing apparatus. This inconsistency also indicates the complexity of the phenomenon of lateralization, and problems with its precise determination. The task components of the functional asymmetry test provide different information than the performance of repeated motor tasks in timed tests. The abundance of test results in the present study, and their interpretations give credence to the usability of the described tests for further research.

What this paper adds?

This study indicates a smaller degree of footedness in soccer players than in non-training individuals. The greatest percentage of differences between the right and left legs, were noted in the results of the rate of movements test and static balance. The soccer players' static balance test results show the presence of training-induced bilateral transfer of balance ability of the legs. The modern testing apparatus used in the present study serves as a type of chronometer that, in its function and design, successfully meets the contemporary requirements.

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References

1. Gabbard C. Foot laterality during childhood: A review. Int J Neurosci. 1993; 72(3-4): 175-182. doi: 10.3109/ /00207459309024106.
2. Gentry V, Gabbard C. Foot-preference behavior: A developmental perspective. J Gen Psychol. 1995; 122(1): 37-45. doi: 10.1080/00221309.1995.9921220.
3. Elias LJ, Bryden MP, Bulman-Fleming MB. Footedness is a better predictor than is handedness of emotional lateralization. Neuropsychologia. 1998; 36(1): 37-43. doi:10.1016/S0028-3932(97)00107-3.
4. Solin J, Golomer E. Pied d'impulsion, lateralite et traumatologie du basketteur [Foot impulsion, lateralization and traumatology of the basketball player]. Médecine du Sport. 1991; 65(4): 205-210.
5. Olex-Zarychta D, Raczek J. The relationship of movement time to hand-foot laterality patterns. Laterality. 2008; 13(5): 439-455. doi:10.1080/13576500802134623.
6. Olex-Zarychta D, Koprowski R, Sobota G, Wrobel Z. Asymmetry of magnetic motor evoked potentials recorded in calf muscles of the dominant and non dominant lower extremity. Neurosci Lett. 2009; 459(2): 74-78. doi:10.1016/j.neulet.2009.05.006.
7. Wieczorek M, Hradzki A. Functional and dynamic asymmetry in youth aged 14 and 16 years (comparative research). Acta Gymnica. 2007; 37(1): 51-61.
8. Witkowski Z, Lyakh W, Gutnik B, Lipecki K, Rutowicz B, Penchev B, Pencheva L. Corrective effects of different training options on development and maturation of professional motor skills from dominant and non-dominant legs of young soccer players. J Physiol Educat Sport. 20011; 11(3): 291-299.

9. Pau M, Ibba G, Attene, G. Fatigue-induced balance impairment in young soccer players. J Athl Training. 2014; 49(4): 454-461. doi: 10.4085/1062-6050-49.2.12.
10. Sannicandro I, Piccinno A, Rosa RA, De Pascalis S. Correlation between functional asymmetry of professional soccer players and sprint. Brit J Sport Med. 2011a; 45: 370-371. Abstract retrieved from Ebsco Host Connection database (Accession No. 66325583). doi:10.1136/ /bjsm.2011.084038.171.
11. Sannicandro I, Piccinno A, Rosa RA, De Pascalis S. Functional asymmetry in the lower limbs of professional soccer players. Brit J Sport Med. 2011b; 45: 370. Abstract retrieved from Ebsco Host Connection database (Accession No. 66325582). doi:10.1136/bjsm.2011.084038.170.
12. Stradijot F, Pittorru GM, Pinna M. The functional evaluation of lower limb symmetry in a group of young elite judo and wrestling athletes. Isokinet Exerc Sci. 2012; 20(1): 13-16. doi: 10.3233/IES-2011-0434.
13. Sannicandro I, Quarto A, Piccinno A, Cofano G, Rosa RA. Lower limb functional asymmetries in young soccer players: Do differences exist between different age groups? Br J Sports Med. 2014; 48: 657-657. Abstract retrieved from CINAHL database (Accession No. 2012505683). doi:10.1136/bjsports-2014-093494.260.
14. Fredericson M, Wolf C. Iliotibial band syndrome in runners: Innovations in treatment. Sports Med. 2005; 35(5): 451-459. doi: 10.2165/00007256-200535050-00006.
15. Antosiak-Cyrak KZ, Kowalski M, Michalski M, Wiczyński G. Lower limbs coordination capabilities test-bed [in Polish]. Pomiary Automatyka Kontrola. 2013; 59(5): 489-492.
16. Antosiak-Cyrak KZ, Wiczyński G, Podciechowska K, Rostkowska EM. Reliability of a new lower-extremity motor coordination test. Pol J Sport Tourism. 2015; 4(24): in print.
17. Gabbard C. Associations between hand and foot preference in 3-to 5-year-old. Cortex. 1992; 28(3): 497-502. doi:10.1016/S0010-9452(13)80158-X.
18. Haaland E, Hoff J. Non-dominant leg training improves the bilateral motor performance of soccer players. Scand J Med Sci Sport. 2003; 13(3): 179-184. doi: 10.1034/j.1600-0838.2003.00296.x.
19. Hale SA, Fergus A, Axmacher R, Kiser K. Bilateral improvements in lower extremity function after unilateral balance training in individuals with chronic ankle instability. J Athl Training. 2014; 49(2): 181-191. doi: 10.4085/1062-6050-49.2.06.
20. McGuine TA, Greene JJ, Best T, Leverson G. Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med. 2000; 10(4): 239-244. PMC1978460.
21. Kostiukow A, Rostkowska E, Samborski W. Assessment of postural balance function. Annales Academiae Medicae Stetinensis. 2009; 55(3): 102-109.