Journal of Physical Education and Sport ® (JPES), Vol.20 (3), Art 188, pp. 1362 – 1368, 2020
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Association between jump asymmetry and reduced performance in the change of direction tests of youth soccer players

YIANNIS MICHAILIDIS[1], CHRISTOS SAVVAKIS[2], VASSILIS PIROUNAKIS[3], DIMITRIOS MIKIKIS[4], KONSTANTINOS MARGONIS[5], THOMAS METAXAS[6]
[1,2,3,4,6]Laboratory of Evaluation of Human Biological Performance, Department of Physical Education and Sports Sciences, Aristotle University of Thessaloniki, GREECE
[5]Department of Physical Education and Sports Sciences, Democritus University of Thrace, Komotini, GREECE

Published online: May 30, 2020
(Accepted for publication: May 18, 2020)
DOI:10.7752/jpes.2020.03188

Abstract
Limb asymmetries is the condition which soccer players may suffer from as they perform many actions on one limb. Furthermore, some sensitive and reliable methods to identify lower limb asymmetries are the use of isokinetic dynamometer, the back squat, the unilateral mid-thigh pull and the unilateral jump tasks. Additionally, it is not clear which is the impact of limb asymmetries on physical performance. The aims of the present study were to: 1) compare single-leg countermovement jump (SLCMJ), single-leg long jump (SLLJ), and single-leg triple jump (SLTJ) between dominant (D) and non-dominant (ND) limbs, 2) to investigate the relationship between inter-limb asymmetry from the above three unilateral jump tests and 505 test and arrowhead change of direction (COD) performance and 3) to examine the relationship of lateral trunk muscles strength asymmetry with COD performance in young soccer players. Forty-two young male soccer players were separated into two groups (Under 10 - U10 and Under 15 - U15) and each one of them performed a SLCMJ, SLLJ, SLTJ, 505 COD test, arrowhead COD test. In order to investigate the relationship between limb asymmetries and performance on unilateral COD tests, paired samples T-test were used and Pearson's to compare the results of their limbs. In U10 significant differences between limbs were observed on SLCMJ (p=0.024) and on SLTJ (p=0.003). SLTJ asymmetries correlated significant with slower arrowhead test times (p=0.039). In U15 significantly differences between limbs were observed on SLCMJ (p=0.032), on arrowhead test (p=0.016) and on 505 test (p=0.018). Asymmetries during SLCMJ were associated with slower performance on 505 COD test (p=0.017). The results indicated that in these two age groups (U10 and U15) of youth soccer players' asymmetry detection is test depended. CMJ can be used in both groups for indentify lower limb asymmetries but this study highlight that the SLTJ for the age of U10 and SLCMJ for the age of U15 appear to be the most appropriate jump tests for identifying limb asymmetries. Additionally, the correlation of asymmetries with agility performance, which is very important for player success, indicates that trainers have to check their players for asymmetries and if there is a difference of greater than 10% it should be eliminated with specific and individualized strength and power programs.
Key Words: single leg jump, 505 test, arrowhead test, performance

Introduction

Change of direction (COD) is a key factor for soccer performance. Bangsbo (1992), observed more than 1200 changes of direction during a game and this shows the importance of this factor. Nimphius (2014) has said that "COD is the ability to change initial direction to a predetermined location and space on a field or court and it depends on many factors like sprint speed, leg strength, leg power, and technique (e.g. foot placement, body posture)".The COD includes three phases which are deceleration, change to new direction, reacceleration. Previous studies mentioned that force production, movement mechanics and strength capacity are crucial factors in order to have better COD performance (Newton et al., 2006).

A lot of the soccer actions are performed with one leg and the way of training them (perform exercises with one leg more than the other) could lead to imbalances between limbs (Newton et al., 2006). These asymmetries could be related with the development of physical abilities like strength, power and balance. A strength difference of >15 % between limbs is a problematic asymmetry because athlete has an increased risk of injury (Nadler et al., 2001). Performance tasks that are under investigation for their relationship with limb asymmetries are COD, sprint and jump performance. The impact of limb asymmetries on physical performance is has not been defined. Some studies indicate that inter-limb asymmetries are correlated with reduction in jump performance (Bishop, Read, McCubbine, and Turner, 2018). Negative effects of asymmetry also, showed in sprinting performance and COD speed performance (Maloney, Richards, Nixon, Harvey, and Fletcher, 2017; Michailidis, Pirounakis, Savvakis, Margonis, and Metaxas, 2019). However, Dos'Santos, Thomas, Jones, and

Corresponding Author: YIANNIS MICHAILIDIS, E-mail: ioannimd@phed.auth.gr

Comfort, 2017a; Lockie et al., 2014 have stated that "jump height and distance asymmetry have no effect on speed or COD performance".

Furthermore, some sensitive and reliable methods to identify lower limb asymmetries are the use of isokinetic dynamometer (Costa Silva, Detanico, Dal Pupo, and Freitas, 2015), the back squat (Dos'Santos, Thomas, Jones, and Comfort, 2017b), the unilateral mid-thigh pull (Dos'Santos, Thomas, Jones, and Comfort, 2017b) and the unilateral jump tasks (Maloney et al., 2017). From all the methods above single leg jumps are the most easy and reliable to perform in a soccer team (Jones and Bampouras, 2010).The single leg jumps which are used most commonly are the single leg countermovement jump (SLCMJ), the single leg long jump (SLLJ), the single leg triple jump (SLTJ) and the single leg drop jump (SLDJ) (Bishop et al., 2018; Dos'Santos et al., 2017a; Lockie et al., 2014; Maloney et al., 2017). Additionally, the trunk muscles of the upper body have a critical role for the stability of the body when performing movements. Also, a stable trunk provides a solid base for torques that are generated by the lower limbs (Behm and Anderson, 2006). Previous studies which were performed on soccer players showed that the strength of trunk muscles have positive relationships with sprinting, jumping and agility performance (Hoshikawa et al., 2013; Nesser, Huxel, Tincher, and Okada, 2008; Prieske et al., 2016). However, the studies on soccer players are limited. An easy and reliable way to estimate isometric endurance strength of lateral trunk muscles is the side bridge test (left and right) (McGill, 2002).

The aims of the present study were: 1) to compare SLCMJ, SLLJ and SLTJ between dominant (D) and non-dominant (ND) limbs in two different age groups of youth soccer players, 2) to investigate the relationship between inter-limb asymmetry from the above three unilateral jump tests with 505 and arrowhead COD performance and 3) to examine the relationship of the lateral trunk muscles strength asymmetry with COD performance (505 test and arrowhead test). It was presumed that significant differences would be found following the comparison of D and ND limb and that greater asymmetries in jump performance would result in the retardation of COD performance. Finally, a positive correlation between lateral trunk muscle strength asymmetry and COD performance was hypothesized.

Material & methods

Participants

Prior to the study, performed a power analysis was conducted which was based on previous studies in youth populations of similar research designs and used a squared multiple correlation of 0.5, effect size of 0.5, a probability error of 0.05 and a power of 0.8. A prior power analysis using G*Power (Version 3.1.9.2, University of Dusseldorf, Germany) (Faul, Erdfelder, Buchner, and Lang, 2009) determined a minimum sample size of 21 participants for each group. Thirty five U10 and forty two U15 youth soccer players from two local soccer academies were invited to participate in this study, and thirty U10 and twenty nine U15 accepted. The criteria to participate in the study was as follows: 1) the participants shouldn't have had any injuries for at least 1 year prior to the study, 2) had a minimum soccer training of two years, 3) should have participated in ≥ 95% of the training sessions of the year, 4) not to be on any medication, 5) not to be early or late maturers. The estimation of maturity status was used to evaluate the 5^{th} inclusion criterion. Twenty-one U10 and twenty-one U15 youth soccer players met the inclusion criteria and completed the study. This study was approved in advance by the local institutional review board, in the spirit of the Helsinki Declaration. It should be noted that all the subjects and their parents were informed about the possible risk factor and a consent form was signed by the parents before participating. Participants' physical characteristics are presented in Table 1.

The participants took part in three training sessions a week which consisted of soccer technical skills, tactical training, speed and sprint workload and small-sided games. Additionally, the total duration of the training session was 90 minutes.

Table 1. Participants' physical characteristics.[†]

	U10 (n=21)	U15 (n=21)
Age (years)	9.6 ± 0.3	14.1 ± 1.4
Training age (years)	2.8 ± 1.3	8.4 ± 2.4
Height (cm)	141.2 ± 5.1	172.0 ± 11.4
Weight (kg)	36.4 ± 6.9	60.8 ± 13.7
Maturity (PHV stage)	Average maturation	Average maturation

[†]Data are presented as mean ± SD.

Procedure

The duration of the study in which participants performed only conventional soccer practice, was three weeks and followed the in-season period. During the first two weeks, each participant was familiarized with the jump and COD tests so as to limit the error of the learning effect. On the first visit following the two weeks, the body mass, standing height, sitting height and the percentage of body fat, of the subjects was measured. On the second and third visits, the fitness tests, were conducted 48 hours after the last training session and with the same sequence but only the U15 participants performed the Trunk flexor and lateral musculature tests. A 15-minute warm-up and a 10-minute cool-down period were also included in the testing. In order to ensure proper hydration during test the subjects consumed water and libitum. All the training sessions as well as the testing sessions were performed at maximal intensity on a soccer field of synthetic turf.

Anthropometric and assessment of maturity status

To measure the body mass to the nearest 0.1 kg an electronic digital scale was used with the participants barefoot and in their underclothes. Their height was also measured to the nearest 0.1 cm (Seca 220e, Hamburg, Germany) and their body fat percentage was estimated based on the sum of four (biceps, triceps, suprailiac, subscapular) skinfold thicknesses measured with a specific caliper (Lafayette, Ins. Co., Indiana) on the right side of the body as described by Slaughter et al. (1988).The body density estimation was calculated according to the Durnin and Rahaman (1967) equation for males younger than 16 and estimated by the equation of Siri (1956).

The equation proposed by Moore et al., (2015) was used to estimate the chronological age at peak height velocity (PHV) of the players. There was a definition of early average and late maturation of the youngsters with an estimated chronological age at PHV of less than 13 years of age, 13-15 years of age and over the age of 15respectively (Sherar, Mirwald, Baxter-Jones, and Thomis, 2005).

Single leg long jump (SLLJ)

The testing began with the subjects standing on the designated testing leg and having their hands on their hips with the other leg bent at the knee. Afterwards, they were instructed to jump as far as possible and to land on the same leg with the horizontal distance between the starting line and the heel of the rear foot being recorded with a tape measure to the nearest centimeter. The participants performed two repetitions with a one minute rest in between and the longest one of them was used. The coefficient of variation for test-retest trials was 4.4% for U10 and 3.8% for U15.

Single leg triple jump (SLTJ)

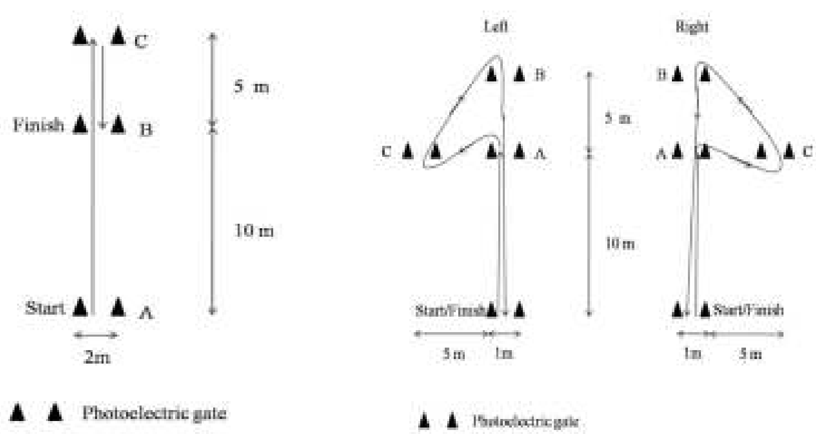
The testing began with the subjects standing on the designated testing leg and having their hands on their hips with the other leg bent at the knee, then were instructed to take three maximal jumps forward (landing on the same leg throughout) trying to minimize the ground contact time after each jump. The horizontal distance between the starting line and the heel of the rear foot was recorded with a tape measure to the nearest centimeter. The participants performed two repetitions with two minute rest in between and the longestone of them was used. The coefficient of variation for test-retest trials was 5.2% for U10 and 4.6% for U15.

Single leg countermovement jump (SLCMJ)

With the subjects standing in an upright position and their feet positioned at a hip width apart the test began with one leg raised from the floor and bent at the knee. They then performed a countermovement to a self-selected depth followed by a quick upwards vertical jump as high as possible with all jumps being performed with arms in akimbo. The VJ height was measured using Myotest equipment (Myotest, Switzerland). The participants performed two repetitions with a one minute rest in between and the best of them was used. The coefficients of variation for test-retest trials were 6.5% for U10 and 4.2% for U15.

505 Change of direction test

The participants began with both feet behind the starting point A. At their own discretion, each subject sprinted forward 15 m till line C and then performed a 180^o turn using the selected leg (two trials with their left and two trials with their right foot) and sprint until line B (Figure 1A). At line B an infrared photoelectric gate (Microgate, Bolzano, Italy) was placed which recorded the time of each attempt. Timing began when the participants broke the electronic beam at the 10 m mark and after the 180^oturn, before sprinting back through the timing gates to complete a recorded distance of 10 m. The participants completed two trials, one to the left and one to the right, having at least 5 minutes of recovery between them. The coefficients of variation for test-retest trials were 4.2% for U10 and 3.6% for U15.



A B

Fig 1. A: 505 change of direction test and B: Arrowhead change of direction test

Arrowhead test

The participants stood behind the starting line in a sprint start position. At their own discretion, each subject ran as fast as possible from the starting line to the middle marks (A), turn to run through the side marks (C), through the far marks (B) and back through the start/finish line (Figure 1B). The participants completed one trial to the left and another to the right, having at least 5 minutes of recovery between them. The time was recorded in seconds to the nearest two decimal places for each direction. The coefficients of variation for test-retest trials were 4.4% for U10 and 3.7% for U15.

Trunk flexor test

The participants sat on the floor and placed their upper body against a support with an angle of 60^o from the floor. Both the in knees and hips were flexed at 90^o. Additionally, their arms were folded across their chest and their hands resting on the opposite shoulder and their feet secured on the ground. Additionally, the subjects were told to maintain their body position while the supporting wedge was pulled back to begin the test. The test ended when the upper body fell below the 60^o angle (McGill, Childs, and Liebenson, 1999).

Lateral musculature

The participants were laying on the floor on their sides with their legs extended. The top foot was placed in front of the lower foot on the floor for support. The participants were instructed to support themselves while lifting their hips off the floor to maintain a straight line over their full body length, and support themselves on one elbow and on their feet. The uninvolved arm was held across their chest with their hand placed on the opposite shoulder. The test ended when the hips returned on the exercise mat (McGill, et al., 1999).

Asymmetry index

Asymmetry index was calculated by the formulae for jumps and COD performance as absolute value as described before by Jones and Bampouras, (2010) (D leg- ND leg/D leg × 100). According to Dos'Santos et al., (2017a),"the dominant leg was the leg that produced the furthest jump or faster COD performance". The same formulae used to calculated asymmetry index of lateral musculature. The dominant side kept the body position (side bridge) for more time than the non dominant side.

Statistical analysis

Data is presented as means ± SD. Since data normality was verified with the 1-sample Kolmogorov-Smirnoff test; therefore, a nonparametric test was not necessary and confidence intervals (CI) (95%) and the coefficiency of variation (CV) were assessed. Differences between D and ND legs were assessed with paired samples t-tests. Pearson's correlation was used for all analyses to investigate the relationships between D-ND asymmetries and lateral trunk muscle asymmetries with COD performance. The level of significance was set at $p<0.05$. The version of the SPSS which was used for all analyses was the18.0 (SPSS Inc., Chicago, IL, USA).

Results

In the Table 2 the mean values of D and ND limb and the differences between limbs for the two groups (U10 and U15) are presented. Correlations between jump tests and lateral abdominal asymmetries with COD performance are shown in Table 3.With, the results indicating that there were significant differences demonstrated between D and ND performance for U10 on SLCMJ (p=0.024) and on SLTJ (p=0.003) and for U15 on SLCMJ (p=0.032), on arrowhead test (p=0.016) and on 505 test (p=0.018). Additionally, asymmetries during the triple test for U10 were associated with slower times on arrowhead test (p=0.039) and for U15 the asymmetries on SLCMJ were associated with a retarded performance on 505 COD test (p=0.017).

Table 2. Dominant vs Non-Dominant limb comparisons for jumps, trunk lateral muscles and COD performance

Variable	Dominant		Non-Dominant		Imbalance (%)	t	p
	Mean	SD	Mean	SD			
			U10				
SLCMJ (cm)	10.56	2.76	9.37*	2.39	10.38	2.703	0.024
SLLJ (cm)	112	14	105	17	5.24	1.340	0.213
SLTJ (cm)	334	40	310*	31	6.94	4.046	0.003
Arrowhead (s)	10.39	0.54	10.40	0.44	0.17	-0.057	0.956
505 (s)	2.83	0.16	2.88	0.15	1.76	1.241	0.246
			U15				
SLCMJ (cm)	15.84	3.48	14.96*	3.69	5.63	2.326	0.032
SLLJ (cm)	186	34	181	33	2.59	1.540	0.141
SLTJ (cm)	559	78	558	79	-0.14	0.039	0.969
Arrowhead (s)	8.87	0.42	9.06*	0.32	-2.33	-2.648	0.016
505 (s)	2.54	0.17	2.59*	0.14	-2.02	-2.597	0.018
	Left side		Right Side				
T. Later. (s)	92.68	30.28	89.16	35.75	2.70	0.744	0.467

COD = change of direction; SLCMJ = single leg countermovement jump; SLLJ = single leg long jump; SLTJ = single leg triple jump; T. Later. = Trunk lateral muscles; * denotes significant difference with dominant limb at p < 0.05

Table 3. Pearson's correlations between jump, trunk lateral imbalances and COD and sprint performance

Variable	SLCMJ		SLLJ		SLTJ		Trunk Lateral Muscles	
	r	p	r	p	r	p	r	p
				U10				
Arrowhead	0.113	0.756	0.018	0.261	0.657	0.039*		
505	0.043	0.906	0.124	0.732	0.283	0.429		
				U15				
Arrowhead	-0.213	0.382	0.069	0.770	-0.341	0.154	0.203	0.404
505	0.540	0.017*	0.268	0.268	0.552	0.114	-0.085	0.728

COD = change of direction; SLCMJ = single leg countermovement jump; SLLJ = single leg long jump; SLTJ = single leg triple jump; * denotes significant correlation at $p < 0.05$

Discussion

The aim of the present study was to determine the performance on SLCMJ, SLLJ and SLTJ between dominant (D) and non-dominant (ND) limbs, to look into the correlation between inter-limb asymmetry from the three unilateral jump tests and 505 and arrowhead COD performance and to examine the relationship of lateral trunk muscles strength asymmetry with COD performance (505 test and arrowhead test) in young soccer players. The results indicated that among these two age groups (U10 and U15) of youth soccer players' asymmetry is test dependent. More specifically for U10, asymmetries between D and ND limb were observed only on SLCMJ and SLTJ. Significant relationships were presented between asymmetries in the SLTJ and arrowhead times. In U15 asymmetries were presented on COD performance and on SLCMJ performance. SLCMJ asymmetries were associated with slower performance on 505 COD test.

With our hypotheses being verified, significant differences were observed during the comparison of D and ND limb on both groups. Furthermore, in the U10 correlations between SLTJ asymmetries and arrowhead performance were observed, whereas in the U15 a relationship was observed between SLCMJ asymmetries and performance on 505 COD test, in agreement with our hypotheses. In contrast, no correlation between lateral trunk muscle strength asymmetry and COD performance was observed for U15 group.

Asymmetries on lower limbs seem to be relevant to injury and performance. More specifically, when the asymmetries are greater than 15% it is suggested to place the soccer player at an increased risk of injury (Nadler et al., 2001) and a negative impact on athletic performance (Maloney et al., 2017). However, other studies mentioned no relationship between strength asymmetries and injury (Bennell et al., 1998) and no negative effect of asymmetries on athletic performance (Lockie et al., 2014).

In both age groups SLCMJ was the type of the jump where more asymmetries were observed than any other jump test. This finding agrees with previous studies. Bishop et al., (2018) mentioned that the difference on SLCMJ was 12.54% and on SLLJ was 6.79%. Lockie et al., (2014) mentioned that the difference on SLCMJ was 10.4% and on SLLJ was 5.1%. It needs to be mentioned that the three studies observed similar results on different samples. More specifically, in the present study, male youth soccer players participated, in the study of Bishop et al., (2018) youth female soccer players participated and in the study of Lockie et al., (2014) male soccer players participated. Vertical jump test is a more sensitive test to identify limb asymmetries. It is not clear why this occurred but the explanation which was given by Bishop et al., (2018) is that children use more horizontal jumps in their daily activities so their body is more familiarized with this kind of jumps than unilateral vertical jumps. In the present study in U15 group between D and ND limbs on two COD tests (505 test and arrowhead test) there were variations but correlations between jump test asymmetries and COD performance were observed only between SLCMJ asymmetries and 505 test performance. On 505 COD test players had to turn only once, whereas on arrowhead the players had to perform three changes of directions. The technical execution is a significant factor for COD performance. Arrowhead test has more turns so the technical ability plays a more significant role than on 505 COD test performance. The CV values of arrowhead were greater than the CV values of 505 COD test and may be this was the reason that no correlations between SLCMJ asymmetries and arrowhead performance were observed. Previous studies showed that asymmetries which are ~10% have as a result a slower change of direction in speed times (Bishop et al., 2019). In contrast some other studies showed that limb asymmetries have no effect on COD performance (Dos'Santos et al., 2017a). Actions such as stopping, turning and kicking the ball occur unilaterally in soccer which could develop an asymmetry between limbs (Hart et al., 2016) which are established from youth ages.

In U10 the asymmetries between D and ND limbs of the SLTJ correlated with arrowhead test time. In U15, as mentioned above SLCMJ asymmetry was the only one with a significant positive correlation with 505 COD performance (Table 3). This means that larger asymmetries may be indicative of slower performance on COD tests. In the present study in both groups the difference between limbs on SLCMJ was > 10% and these asymmetries resulting in a negative impact on COD performance in agreement with previous references where asymmetries are >10% and being suggested as having a negative impact on physical performance (Bishop et al., 2018). SLCMJ seems to be more sensitive to identify limb asymmetries in U10 and U15 youth soccer players. Also, in U15 this jump test shows stronger relationship to decrements of 505 COD performance than two horizontal jumps. However, in U10 the SLTJ correlated with decrements on arrowhead performance. Additionally, SLTJ is a repeated effort test which requires more coordination abilities than the single effort tests. This is an element that practitioners have to notice when young soccer players are measured.

Jump tests that were used in the present study to identify the asymmetries, are tests that used to measure lower limb power. Strength is a critical factor for greater performance on jumping, sprinting and change of direction (Wong, Chamari, Dellal, and Wisloff, 2009). Additionally, the technique could affect performance on the above tests but only through biomechanical analysis can we understand the merge of technique effect with familiarization potentially helping in decreasing this effect. Furthermore, another aim of the study was to examine the relationship of lateral trunk muscles strength asymmetry with COD performance (505 test and arrowhead test) in U15 young soccer players and its results indicating that there were not any significant differences between left and right lateral endurance strength trunk muscles. Also, there were not any relationships between lateral trunk muscle strength with COD performance. This lack of relationships could be explained by the following reasons: 1) not observed significant differences between left and right lateral trunk muscles, 2) the tests which were used measure the strength endurance of the trunk muscles and not the strength of these muscles, and 3) core endurance strength plays a minor role to change of direction.

In the present study McGill's et al., (1999) core stability tests were used which were designed to measure muscle endurance of the core musculature. Previous studies mentioned that the above tests which were used for the measure of the trunk muscles strength endurance are reliable (McGill's et al., 1999). As previously stated the variations of the specific group of participants were 3.27%. Also, the specificity of the test with the kind of performance action (turn on COD tests) probably plays a significant role for the lack of relationships. The tests use an isometric muscle contraction and measure muscle endurance. The turns of COD tests are characterized by power and maximum force production, and lasting milliseconds. However, Nesser et al., (2008) mentioned that lateral bridge test moderately correlated with 20-yd sprint, 40-yd sprint and shuttle run performance. Other studies indicate that the increase of muscle trunk strength could enhance sport performance (Hoshikawa et al., 2013; Prieske et al., 2016).

Although in the present study no significant correlation between lateral trunks muscle endurance strength and COD performance was found, authors' opinion is that trunk muscles play a significant role to many soccer actions like change of direction. The studies performed on soccer players are limited. Determination of the role of core strength requires additional research.

Previous studies mentioned that the variability during test protocols have to be smaller than limb differences, due to the fact that in other case the conclusions for asymmetries are not clear (Exell, Irwin, Gittoes, and Kerwin, 2012). In the present study limb asymmetries in jump tests were greater than CV values. Additionally, all CV values were <10% which is considered acceptable (Cormack, Newton, McGuigan, and Doyle, 2008). One of the limitations of this study is that the strength of the limbs was not measured and only power tests like jumps were used. As mentioned above, strength could play a significant role in sprinting and jumping performance. Also, for lateral trunk muscles tests that measure core strength endurance were used. A more specific strength test for these muscles could be more appropriate. Another limitation is that the results are only applicable to youths U10 and U15 male soccer players. To provide comparisons across different youth ages, bigger samples, different gender and use more specific equipment to measure their strength should be aimed in future research. Unilateral jump tests can be used to estimate limb asymmetries in an easy and fast way in youth soccer players as soccer is a sport which could lead to lower limb asymmetries after asymmetries between D and ND limbs observed at a young age. The correlation between jump test asymmetries and COD test performance shows that asymmetries could have a negative impact on soccer athletic performance. Trainers who have observed limb differences need to minimize them under 10% with specific training programs.

Conclusions

Trainers could use SLCMJ in U15 and SLTJ in U10 to measure lower limb asymmetries with an easy and fast way. If there is a difference of greater than 10% it should be eliminated with specific and individualized strength and power programs. The core training is necessary for optimal soccer performance. This kind of exercises in players' training schedule per session will be beneficial to improve the muscle strength around the hip joint.

Conflicts of interest

The authors report no conflict of interest.

References

Bangsbo, J. (1992). Time and motion characteristics of competitive soccer. *Science and Football, 6*, 34-40.

Behm, D.G., & Anderson, K.G. (2006).The role of instability with resistance training. *J Strength Cond Res, 20,* 716–722.

Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D., & Cirone J. (1998). Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *Brit J Sport Med,32*, 309-314.

Bishop, C., Read, P., McCubbine, J., & Turner, A. (2018). Vertical and horizontal asymmetries are related to slower sprinting and jump performance in elite youth female soccer players. *J Strength Cond Res*, In Press doi: 10.1519/JSC.0000000000002544.

Bishop, C., Turner, A., Maloney, S., Lake, J., Loturco, I., Bromley, T., & Read, P. (2019).Drop Jump Asymmetry is Associated with Reduced Sprint and Change-of-Direction Speed Performance in Adult Female Soccer Players. *Sports (Basel.), 7*(1), pii: E29. doi: 10.3390/sports7010029.

Cormack, S., Newton, R., McGuigan, M., & Doyle, T. (2008). Reliability of measures obtained during single and repeated countermovement jumps. *Int J Sports Physiol Perform, 3*, 131–144.

Costa Silva, J., Detanico, D., Dal Pupo, J., &Freitas, C. (2015). Bilateral asymmetry of knee and ankle isokinetic torque in soccer players u20 category. *Braz J Kinanthrop Hum Perform, 17,* 195–204.

Dos'Santos, T., Thomas, C., Jones, P., & Comfort, P. (2017b). Asymmetries in single and triple hop are not detrimental to change of direction speed. *Journal of Trainology, 6*, 35–41.

Dos'Santos, T., Thomas, C., Jones, P., & Comfort, P. (2017a) Assessing muscle strength asymmetry via a unilateral stance isometric mid-thigh pull. *Int J Sports Physiol Perform, 12*, 505–511.

Durning, S., & Rahaman, M. (1967).The assessment of the amount of fat in the human body from measurements of skinfold thickness. *Brit J Nutr, 21*, 681–689.

Exell, T.A., Irwin, G., Gittoes, M.J.R., &Kerwin, D.G. (2012). Implications of intra-limb variability on asymmetry analyses.*J Sports Sci, 30*, 403-409

Faul, F., Erdfelder, E., Buchner, A., & Lang A-G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods, 41,* 1149-1160.

Hart, N., Nimphius, S., Weber, J., Spiteri, T., Rantalainen, T., Dobbin, M., & Newton, R. (2016). Musculoskeletal asymmetry in football athletes: A product of limb function over time. *Med Sci Sports Exerc, 48*, 1379–1387.

Hoshikawa, Y., Iida, T., Muramatsu, M., Ii, N., Nakajima, Y., Chumank, K, & Kanehisa H. (2013).Effects of stabilization training on trunk muscularity and physical performances in youth soccer players. *J Strength Cond Res, 27*(11), 3142–3149.

Jones, P.A., & Bampouras, T.M. (2010). A comparison of isokinetic and functional methods of assessing bilateral strength imbalance. *J Strength Cond Res, 24,* 1553-1558.

Lockie, R., Callaghan, S., Berry, S., Cooke, E., Jordan, C., Luczo, T., & Jeffriess M. (2014). Relationship between unilateral jumping ability and asymmetry on multidirectional speed in team-sport athletes. *J Strength Cond Res, 28*, 3557–3566.

Maloney, S., Richards, J., Nixon, D., Harvey, L., & Fletcher, I. (2017). Do stiffness and asymmetries predict change of direction performance? *J Sports Sci, 35*, 547–556.

McGill, S.M. (2002). Low Back Disorders. Evidence-Based Prevention and Rehabilitation: Human Kinetics.

McGill, S.M., Childs, A., & Liebenson, C. (1999). Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Arch Phys Med Rehabil, 80*, 941–944.

Michailidis, Y., Pirounakis, V., Savvakis, C., Margonis, K., & Metaxas, T. (2019). The influence of unilateral jumping asymmetry on acceleration and speed performance in U10 and U15 groups of youth soccer players. *TRENDS in Sport Sciences, 26*(4), 145-151.

Moore, S.A., McKay, H.A., Macdonald, H., Nettlefold, L., Baxter-Jones, A.D., Cameron, N.&Brasher P.M. (2015).Enhancing a Somatic Maturity Prediction Model. *Med Sci Sports Exerc, 47*(8), 1755-64.

Nadler, S.F., Malanga, G.A., Feinberg, J.H., Prybicien, M., Stitik, T.P., & DePrince, M. (2001). Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes: a prospective study. *Am J Phys Med Rehab, 80,* 572-577.

Nesser, T.W., Huxel, K.C., Tincher, J.L., & Okada, T. (2008).The relationship between core stability and performance in division I football players. *J Strength Cond Res, 22* (6), 1750–1754.

Newton, R.U., Gerber, A., Nimphius, S., Shim, J.K., Doan, B.K., Robertson, M., Pearson, D.R., Craig, B.W., Hakkinen, K., & Kraemer, W.J. (2006).Determination of functional strength imbalance of the lower extremities. *J Strength Cond Res, 20*, 971-977.

Nimphius, S. (2014). Chapter 13-Increasing agility. Chapter taken from Human Kinetics Handbook of High-Performance Training for Sports ISBN-13: 978-1-4504-4482-8.

Prieske, O., Muehlbauer, T., Borde, R., Gube, M., Bruhn, S., Behm, D.G., & Granacher U. (2016). Neuromuscular and athletic performance following core strength training in elite youth soccer: Role of instability. *Scand J Med Sci Sports, 26*, 48-56.

Sherar, L.B., Mirwald, R.L., Baxter-Jones, A.D., & Thomis, M. (2005). Prediction of adult height using maturity-based cumulative height velocity curves. J Pediatr, 147(4): 508-514.

Siri, W.E. (1956). The gross composition of the body. *AdvBiol Med Phys, 4*, 239-280.

Slaughter, M.H., Lohman, T.G., Boileau, R.A., Horswill, C.A., Stillman, R.J., Van Loan, M.D., & Bemben, D.A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Hum Biol, 60*, 709–723.

Wong, P-L., Chamari, K., Dellal, A., & Wisloff, U. (2009).Relationship between anthropometric and physiological characteristics in youth soccer players. *J Strength Cond Res, 23*, 1204-1210.