RELATIONSHIP BETWEEN LOWER LIMB ASYMMETRIES AND FUNCTIONAL CAPACITIES IN WOMEN IN BASKETBALL: A CASE STUDY

Francesca D'Elia[1], Vincenzo Rago[2], Georgios Ermidis[3] and Gaetano Raiola[1]

[1]*University of Salerno, Italy*
[2]*University of Porto, Centre of Research, Education, Innovation and Intervention in Sports, Portugal*
[3]*Parthenope University, Department of Sports sciences and wellness, Naples, Italy*

Original scientific paper

Abstract
Professional Basketball has been reported to impose important physiological loads on players during competition. Indeed, basketball games comprise many high speed movements in forward and lateral directions combined with decelerations from frequent sprint efforts. Explosive vertical jumps may be executed up to 50 times per game. The lower limb asymmetry index (ASI) has been commonly employed to quantify neuromuscular deficits between legs. This index is used to identify athletes at potential risk for injury; the weaker limb is typically predisposed to injury. Current evidence indicates that a difference of 10-15% between legs with performance on isokinetic strength and vertical jump may be the threshold for increased risk of injury. Therefore, the quantification of neuromuscular asymmetries in the lower limbs is an important part of identifying young athletes who may be at risk of injury and monitoring the progress of athletes in rehabilitation programs following injury. The purpose of this study was to analyze the correlation between lower limb ASI and functional capacities. Method is experimental with a complex approach of case study. Results don't show unique data and it has to deep the investigation with a large sample to verify if to carry out a better results for a critical plus knowledge.

Key Words: *team sports, range of motion, countermovement jump, asymmetry, repeated sprint ability.*

Introduction

Professional Basketball has been reported to impose important physiological loads on players during competition (Manzi et al., 2010). Indeed, a basketball game comprises many high speed movements in forward and lateral directions combined with decelerations from frequent sprint efforts (Montgomery, Pyne, & Minahan, 2010). Explosive vertical jumps may be executed up to 50 times per game (Ben Abdelkrim, El Fazaa, & El Ati, 2007). Consequently, physical conditioning is considered as a prerequisite to compete at elite level in modern basketball. However, these action are mostly unilateral, potentially leading to asymmetric adaptations of the lower extremities (Hewit, Cronin, & Hume, 2012a; Menzel et al., 2013).The quantification of neuromuscular deficits between legs is critical in order to identify individuals who may be at risk of injury, and to optimize strength and conditioning training (Hewit, Cronin, & Hume, 2012b). Substantial lower limb neuromuscular asymmetry with regard to strength and power has been described as an important risk factor for sport injuries and linked to decrements in sports performance (Hewit et al., 2012b; Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007; McElveen, Riemann, & Davies, 2010; Newton et al., 2006)For instance, the connection between strength / power asymmetry and injury risk /weak physical capacity could be related to the inability of a weaker lower limb to produce and / or absorb the same amount of force that a stronger limb can (Fort-Vanmeerhaeghe, Gual, Romero-Rodriguez, & Unnitha, 2016). Previous studies on lower limb asymmetry have focused on strength and power as measured by isokinetic dynamometer (Newton et al., 2006; Rahnama, Lees, & Bambaecichi, 2005). However, motorized dynamometers are expensive and do not accurately mimic sport-specific movement of the lower limbs. The single-leg vertical jump may provide an alternative solution, as it has demonstrated to be a sensitive functional task to detect power asymmetries between legs in basketball players (Fort-Vanmeerhaeghe et al., 2016; Fort-Vanmeerhaeghe, Montalvo, Sitja-Rabert, Kiefer, & Myer, 2015).However, it is important to note that an athlete's performance depends on multiple neuromuscular capacities, including range of motion, balance, agility. Indeed, simple clinical assessments of joint range of motion (ROM) have been typically performed on a one-off basis as part of a preseason screening battery in elite baseball (Whiteley, 2016). The assessment of ROM more regularly during competitive periods may provide greater information pertaining to structural fatigue and potential injury risk / readiness. Indeed, structural assessments quantifying hip and knee ROM have shown good reliability and validity after match play in youth soccer players (Paul et al., 2014). The simple and quick nature of ROM assessments evaluating key anatomical regions may provide a greater understanding of structural status and potential injury risk. In addition, the Star Excursion Balance test (SEBT) has been shown to be a reliable measure and has validity as a dynamic balance test to predict risk of lower extremity injury, and to identify dynamic balance deficits (Gribble, Hertel, & Plisky, 2012).

However, at best of our knowledge, no previous study has considered neither ROM nor dynamic balance asymmetries as potential predictor of functional performance in women basketball players. The lower limb asymmetry index (ASI) has been commonly employed to quantify neuromuscular deficits between legs (Fort-Vanmeerhaeghe et al., 2015; Overmoyer & Reiser, 2013). This index is used to identify athletes at potential risk for injury; the weaker limb is typically predisposed to injury (Hewit et al., 2012a). Current evidence indicates that a difference of 10-15% between legs with performance on isokinetic strength and vertical jump may be the threshold for increased risk of injury (Hewit et al., 2012a; McElveen et al., 2010). Therefore, the quantification of neuromuscular asymmetries in the lower limbs is an important part of identifying young athletes who may be at risk of injury and monitoring the progress of athletes in rehabilitation programs following injury. The purpose of this study was to analyze the correlation between lower limb ASI and functional capacities.

Methods

Participants

14 semi-professional female basketball players (Mean ± SD, Age=17.7 ± 1.9, body mass= 67.7 ± 13.3, height= 173.07 ± 6.21, fat mass= 21.8 ± 5.1)competing in the Italian 3rd tier of Italian Basketball system participated in this study. All players had the right leg as dominant limb. The study was conducted in the context of the regular team assessments under requirements of the team' coaching and medical departments.

Experimental design

All players were evaluated in September 2017 at their training center. The protocol included an interview, anthropometry, and a series of field-based physical tests. Players were interviewed regarding the number of years of involvement in soccer and hours per week of regular training throughout a competitive season. Each player was tested on 2 occasions within a 1-week period. Anthropometric dimensions, ROM, ball throwing, sprint time, agility and repeated sprint ability were measured during the initial visit. Jumping tests and intermittent endurance performances were assessed during the second visit. With the exception of anthropometry and ROM in the treatment room, all tests were administered indoors on a basketball court with tartan. Prior to testing of physical capacities, the players performed their habitual 12-min warm-up consisting of jogging and stretching exercises under the supervision of the team' strength and conditioning coach, as well as familiarization trials of each test under the examiners' supervision. Players wore basketball clothing and shoes during all tests.

Lower limb range of motion

Hip and knee dominant and non-dominant limb ROM were measured actively on the sagittal plane using a digital goniometer with spirit level (004BB, Creative Health Inc., Plymouth, USA). according to the procedure of Borms and Van Roy (2003). Measurements were done in the same order by the trained technician on all subjects as hip extension, hip flexion, knee extension and knee flexion. Percentage of difference between dominant and non-dominant ROM was considered as bilateral asymmetry. Flexion: extension ratio was also calculated and considered as indicator of muscle imbalance.

Dynamic balance

The SEBT consisted of 8 lines of cloth measuring tape adhered to the floor with clear packing tape 45° apart from each other, in the shape of an asterisk. Before testing, the lengths of both lower extremities of each subject were measured by the investigator from the anterior superior iliac spine of the hip to the distal end of the medial malleolus (Gribble et al., 2012). While testing, subjects stood on one leg in the middle of the star and reached as far as possible with their toes of the opposite leg, holding their hands on their hips, and keeping the heel of the stance leg on the ground. A mark on the tape was made by the investigator with an erasable marker and the distance was read from the center of the star to the mark (Gribble et al., 2012). After each reach, the distance was recorded and the mark erased so that the subject did not use that mark as target for the next trial. The subject first practiced the test 3 times. The final value was given by 3 lengths averaged and expressed in relation to leg length.

Upper limb power

Upper limb power was measured using a 3-kg non-bouncing medicine ball, and a metric tape affixed on the ground. In the overhead medicine ball throwing test, the subject stood at a line with the feet side by side and slightly apart, and facing the direction to which the ball was to be thrown. The ball was held with the hands on the side and slightly behind the center. Player were instructed to bring back behind the head, then thrown vigorously forward as far as possible. The subjects were permitted to step forward over the line after the ball is released, and is in fact encouraged to do so in maximizing the distance of the throw. Three attempts were allowed, and the distance reached by the ball on the floor was recorded as criterion measure for upper limb power.

Lower limb power

CMJ parameters were collected using the Myotestaccelerometric system (Myotest SA, Sion, Switzerland). The Myotest device (dimensions: 5.4 x 10.2 x 11.1 cm; weight: 58 g) contains a 3D inertial accelerometer (68 g) that allows vertical acceleration to be recorded at a sampling frequency of 500 Hz, as previously described(Rago et al., 2018). The device was perpendicularly attached to a large (8.5 cm) Velcro elastic belt. The device was fixed at hip level on the left side of the body, as indicated by the manufacturer. Participants performed a three CMJ efforts in total (i) a free hands mono-podal vertical jump, and two monopodial CMJ with free hands as: (ii) standing right leg (CMJ-R) and (iii) and standing left leg (CMJ-L). All players had 2 practice trials and 3 assessment jumps. The trial showing the best jump height was selected as criterion measure, independently of the other CMJ parameters (i.e. power, force, velocity etc.). The equipment is reliable for measuring CMJ height using the flight-time calculation method (Rago et al., 2018). Peak power was estimated using Sayers' equation (Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999).

Upper limb power
Upper limb power was measured using a 3-kg non-bouncing medicine ball, and a metric tape affixed on the ground. In the overhead medicine ball throwing test, the subject stood at a line with the feet side by side and slightly apart, and facing the direction to which the ball was to be thrown. The ball was held with the hands on the side and slightly behind the center. Player were instructed to brought back behind the head, then thrown vigorously forward as far as possible. The subjects were permitted to step forward over the line after the ball is released, and is in fact encouraged to do so in maximizing the distance of the throw. Three attempts were allowed, and the distance reached by the ball on the floor was recorded as criterion measure for upper limb power.

Sprint time
Acceleration (5-m) and straight sprint (15-m) capacity was evaluated with a 20-m sprint test. Elapsed times were measured using 3 pairs of photoelectric cells (Microgate, Bolzano, Italy), positioned at the starting line and at 5 and 15 m. Players were instructed to run as fast as possible from a standing position 30 cm behind the starting line, over a cone placed on 20 m. This strategy was based on practical experience, since players tend to break before reaching the end. The better (fastest) of 2 trials was retained for analysis.

Agility
The players' capacity of changing direction was assessed using the T-test (Semenick, 1990). The subject began with both feet 30 cm behind the starting point (A). The player sprinted forward 10 m to point B and touched a marker (cone) with the right hand, then sprinted 5-m to the left running sideward and touched another marker (C) with the left hand, then sprinted 10 m to the right running sideward and touched a third marker (D) with the right hand, and finally sprinted back, still running sideward to point B and touched the marker with the left hand, after which he turned 90° and returned to the starting point A running backward through the finish line.

One pair of photoelectric cells was placed at the starting/finishing point (A) to record the elapsed time. Players were instructed to run as fast as possible. The best (lowest time) of 2 trials was retained for analysis.

Repeated sprint ability
The RSA test consisted of six 40m (20 + 20m) shuttle sprints separated by 20 s of passive recovery, described by Rampinini et al. (2007). The athletes started from a line, sprinted for 20 m, touched a line with a foot, and came back to the starting line as fast as possible. After 20 s of passive recovery, the soccer player started again. Each single shuttle time was recorded using a photocells system (Microgate, Bolzano, Italia). Five seconds before the start of each sprint, subjects assumed the ready position and waited for the start signal. The mean time between shuttles was retained as indicator of RSA.

Yo-yo intermittent recovery level 1
The capacity of performing intermittent exercise was obtained from the YYIR1 required repeated 2 x 20-m runs (shuttles), separated by a 10-s rest period, between the start and finish line at progressively increased speeds controlled by audio bleeps from a tape recorder (Bangsbo, Iaia, & Krustrup, 2008). The aim of the test was to perform as many shuttles as possible. When the player failed twice to reach the finish line in time, the distance covered was recorded as the test score. Only one test was performed. The total distance covered in the YYIR1 was considered as final score and indicator of capacity of performing intermittent exercise.

Data analyses
ASI was quantified as the percentage of difference between D and ND limb for ROM, SEBT and monopodial CMJ (Impellizzeri et al., 2007). Pearson correlation coefficients (r, with 90% confidence intervals, CIs) were calculated to quantify the association between ASI and functional capacities. To interpret the magnitude of the correlation coefficients, the following criteria were used: $r \leq 0.10$ (trivial), $0.10 < r < 0.30$ (small), $0.30 < r < 0.50$ (moderate), $0.50 < r < 0.70$ (large), $0.70 < r < 0.90$ (very large) and $0.90 < r < 1$ (almost perfect). If the CIs overlapped positive and negative values, the effect was deemed unclear (Batterham & Hopkins, 2006). All data were reported as Mean ± SD for each variable. Data analysis was performed using a customized Excel spreadsheet (Hopkins, 2007).

Results

Descriptive values of lower limb asymmetries are reported in table 1. Hip Flex ASI showed negatively moderate correlations with ball throwing (r=-0.38 ± 0.34). Knee Flex:Ext Ratio ASI showed negative correlations with ball throwing and CMJ height (r= -0.60 ± 0.32; -0.51 ± 0.36). Dynamic balance ASI was negatively correlated with ball throwing and agility time during the T-test (r=-0.76 ± 0.22 and 0.38 ± 0.29). ASI of CMJ height and CMJ power was negatively correlated with ball throwing (r ranging from -0.68 to -0.38). CMJ power ASI was also negatively correlated with 5-m sprint time (r= -0.59 ± 0.32).

Hip Flex:Ext Ratio ASI showed a negatively large correlation with performance in the YYIR1 (r=-0.56 ± 0.34).

A detailed description of the relationship between lower limbs asymmetries and functional capacities is reported in table 2.

Table 1. Bilateral asymmetries between dominant and non-dominant limb in women basketball. Descriptive values of lower limb asymmetries.

Variable	Dominant		Non-dominant		ASI (%)	
	Mean ± SD	CV (%)	Mean ± SD	CV(%)	Mean ± SD	CV(%)
Hip Flex. ROM (°)	24.4 ± 4.6	19.0	24.8 ± 5.3	21.4	10.2 ± 7.2	70.8
Hip Ext. ROM (°)	91.2 ± 9.7	10.6	94.9 ± 8.6	9.0	6.6 ± 3.7	56.1
Hip Flex : Ext Ratio	7:10	19.2	1:10	9.4	277.4 ± 84.3	30.4
Knee Flex. ROM (°)	50.0 ± 5.3	10.6	50.5 ± 7.3	14.4	6.9 ± 5.1	74.0
Knee Ext. ROM (°)	165.4 ± 6.6	4.0	160.2 ± 10.2	6.4	3.8 ± 3.4	90.8
Knee Flext : Ext Ratio	1: 3	11.9	7: 8	4.8	223.7 ± 31.5	14.2
Dynamic balance (cm)	7.5 ± 0.2	3.7	7.6 ± 0.3	4.1	5.23 ± 3.9	75.9
CMJ Height (cm)	21.6 ± 4.6	21.2	21.1 ± 5.2	24.7	12.1 ± 7.4	61.0
CMJ Power ($W \cdot Kg^{-1}$)	24.2 ± 9.0	37.2	28.6 ± 13.5	47.4	34.03 ± 22.4	66.06
ROM= Range of motion, CMJ= Counter-movement jump, ASI= lower limb asymmetry index						

Table 2. Relationship between lower limbs asymmetries and functional capacities.

	Hip flex ASI	Hip Ext ASI	Hip Flex: Ext Ratio ASI	Knee flex ASI	Knee ext ASI	Knee Flex: Ext Ratio ASI	Dynamic balance ASI	CMJ Height ASI	CMJ Power ASI
Ball Throwing	**-0.38 ± 0.34**	-0.10 ± 0.46	-0.37 ± 0.41	0.44	0.17 ± 0.45	**-0.60 ± 0.32**	**-0.76 ± 0.22**	**-0.68 ± 0.27**	**-0.38 ± 0.31**
CMJ height	-0.02 ± 0.46	-0.05 ± 0.46	0.16 ± 0.45	0.05 ± 0.46	0.04 ± 0.46	**-0.51 ± 0.36**	-0.05 ± 0.46	0.12 ± 0.45	**-0.48 ± 0.37**
CMJ Power	0.02 ± 0.46	-0.02 ± 0.46	-0.01 ± 0.46	0.03 ± 0.46	0.15 ± 0.45	-0.23 ± 0.44	0.15 ± 0.45	-0.36 ± 0.41	-0.07 ± 0.46
5-m time	0.01 ± 0.46	-0.07 ± 0.46	0.12 ± 0.45	0.08 ± 0.46	-0.05 ± 0.46	0.56 ± 0.34	-0.15 ± 0.45	0.03 ± 0.46	**-0.59 ± 0.32**
15-m time	-0.03 ± 0.46	0.05 ± 0.46	0.39 ± 0.40	-0.10 ± 0.46	-0.12 ± 0.45	0.25 ± 0.44	-0.29 ± 0.43	0.01 ± 0.46	-0.14 ± 0.45
Agility	0.06 ± 0.46	0.07 ± 0.46	-0.01 ± 0.46	0.01 ± 0.46	-0.10 ± 0.46	-0.08 ± 0.46	**-0.38 ± 0.29**	-0.16 ± 0.45	-0.05 ± 0.46
RSA	-0.08 ± 0.46	-0.09 ± 0.46	-0.21 ± 0.44	0.00 ± 0.46	0.08 ± 0.46	**0.55 ± 0.34**	0.23 ± 0.44	-0.21 ± 0.44	**0.46 ± 0.38**
YYIR1	-0.36 ± 0.41	-0.27 ± 0.43	**-0.56 ± 0.34**	-0.16 ± 0.45	0.33 ± 0.42	0.49 ± 0.37	-0.16 ± 0.45	0.27 ± 0.43	-0.09 ± 0.46

Discussion and conclusion

Hip Flex ASI showed negatively moderate correlations with ball throwing and CMJ force (r=-0.38 ± 0.34 and r=-0.39 ± 0.37)>>. Maybe CMJ force requires a symmetric ROM at the hip?Knee Flex:Ext Ratio ASI showed negative correlations with ball throwing, CMJ height and CMJ force (r= -0.60 ± 0.32, -0.51 ± 0.36, -0.56 ± 0.34)>>. Maybe ball throwing requires a proper symmetry at the knee and referes to jump power. Dynamic balance ASI was negatively correlated with ball throwing and agility time during the T-test (r=-0.76 ± 0.22 and 0.38 ± 0.29).

Players with asymmetry in the SEBT have weak ball throwing and agility. Why? Does ball throwing and t-test require dynamic balance? ASI of CMJ height, CMJ power and CMJ force was negatively correlated with ball throwing (r ranging from -0.68 to -0.38). CMJ power ASI was also negatively correlated with 5-m sprint time (r= -0.59 ± 0.32). Players with an asymmetry in CMJ parameters have a weak jump power (assessed with two feet) and sprint capacity? CMJ velocity ASI reported negatively moderate-to-large correlations with CMJ height, CMJ power, CMJ velocity and both 5-m and 15-m sprint time (r= -0.55 ± -0.34, -0.42 ± 0.39, -0.45 ± 0.38, -0.55 ± 0.34 and 0.58 ± 0.33, respectively. Players that have an asymmetry in CMJ execution have a poor neuromuscular capacity? Specifically when assessing jumping tasks, it is important to assess movements in all axes in order to capture a comprehensive snapshot of the athlete's performance(Myer et al., 2011). As such, it may be important to assess various components of the neuromuscular system in all three dimensions to best detect relevant lower limb asymmetries (Meylan, Nosaka, Green, & Cronin, 2010). The negative correlation between Hip Flex:Ext Ratio ASI and endurance capacity (r=-0.56 ± 0.34) indicates that players with an imbalanced ROM over hip flexors and extensors muscles have a poor endurance capacity. Can exist any link between ROM imbalances at hips and intermittent endurance? Maybe, players have also to change direction during YYIR1, using hip flexors/extensor.

Similarly, the positive correlation between Knee Flex:Ext ASI and CMJ power with RSA_{best} and RSA_{mean} (r ranging from 0.46 to 0.65) suggest that players with an asymmetric balance in terms of ROM over hamstring and quadriceps, and an asymmetric jump power, have a likely weak anaerobic capacity. Can there be any link between ROM imbalances at knee, jump power and RSA?

Maybe players have also to change direction during RSA, using knee flexors/extensor. Finally, it has to deep the investigation with a large sample to verify if to carry out better results for a critical elaboration of plus knowledge. So, it probably can satisfy the several questions that are carried out. In perspective, this study has the first step to investigate the expected issue and for to give a response at several question.

References

Bangsbo, J., Iaia, F.M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. *Sports Med, 38*(1), 37-51.

Batterham, A.M., & Hopkins, W.G. (2006). Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform, 1*(1), 50-57.

Ben Abdelkrim, N., El Fazaa, S., & El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med, 41*(2), 69-75.

Borms, J., & Van Roy, P. (2003). Flexibility. In R. Eston & T. Reilly (Eds.), Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data: Volume One: Anthropometry and Volume Two: Exercise Physiology (pp. 115-144). London: Taylor & Francis.

Fort-Vanmeerhaeghe, A., Gual, G., Romero-Rodriguez, D., & Unnitha, V. (2016). Lower Limb Neuromuscular Asymmetry in Volleyball and Basketball Players. *Journal of Human Kinetics, 50,* 135-143.

Fort-Vanmeerhaeghe, A., Montalvo, A. M., Sitja-Rabert, M., Kiefer, A. W., & Myer, G. D. (2015). Neuromuscular asymmetries in the lower limbs of elite female youth basketball players and the application of the skillful limb model of comparison. *Phys Ther Sport, 16*(4), 317-323.

Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *Journal of Athletic Training, 47*(3), 339-357.

Hewit, J. K., Cronin, J. B., & Hume, P. A. (2012a). Asymmetry in multi-directional jumping tasks. *Phys Ther Sport, 13*(4), 238-242.

Hewit, J. K., Cronin, J. B., & Hume, P. A. (2012b). Multidirectional Leg Asymmetry Assessment in Sport. *Strength & Conditioning Journal, 34*(1), 82-86.

Hopkins, W. G. (2007). A Spreadsheet for Deriving a Confidence Interval, Mechanistic Inference and Clinical Inference from a P Value. Sportscience, 11, 16-21.

Impellizzeri, F. M., Rampinini, E., Maffiuletti, N., & Marcora, S. M. (2007). A vertical jump force test for assessing bilateral strength asymmetry in athletes. *Med Sci Sports Exerc, 39*(11), 2044-2050.

Manzi, V., D'Ottavio, S., Impellizzeri, F. M., Chaouachi, A., Chamari, K., & Castagna, C. (2010). Profile of weekly training load in elite male professional basketball players. *J Strength Cond Res, 24*(5), 1399-1406.

McElveen, M. T., Riemann, B. L., & Davies, G. J. (2010). Bilateral comparison of propulsion mechanics during single-leg vertical jumping. *J Strength Cond Res, 24*(2), 375-381.

Menzel, H. J., Chagas, M. H., Szmuchrowski, L. A., Araujo, S. R., de Andrade, A. G., & de Jesus-Moraleida, F. R. (2013). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *J Strength Cond Res, 27*(5), 1370-1377.

Meylan, C. M., Nosaka, K., Green, J., & Cronin, J. B. (2010). Temporal and kinetic analysis of unilateral jumping in the vertical, horizontal, and lateral directions. *J Sports Sci, 28*(5), 545-554.

Montgomery, P. G., Pyne, D. B., & Minahan, C. L. (2010). The physical and physiological demands of basketball training and competition. *Int J Sports Physiol Perform, 5*(1), 75-86.

Myer, G. D., Schmitt, L. C., Brent, J. L., Ford, K. R., Barber Foss, K. D., Scherer, B. J., . . . Hewett, T. E. (2011). Utilization of modified NFL combine testing to identify functional deficits in athletes following ACL reconstruction. *J Orthop Sports Phys Ther, 41*(6), 377-387.

Newton, R. U., Gerber, A., Nimphius, S., Shim, J. K., Doan, B. K., Robertson, M., . . . Kraemer, W. J. (2006). Determination of functional strength imbalance of the lower extremities. *J Strength Cond Res, 20*(4), 971-977.

Overmoyer, G. V., & Reiser, R. F., 2nd. (2013). Relationships between asymmetries in functional movements and the star excursion balance test. *J Strength Cond Res, 27*(7), 2013-2024

Paul, D. J., Nassis, G. P., Whiteley, R., Marques, J. B., Kenneally, D., & Chalabi, H. (2014). Acute responses of soccer match play on hip strength and flexibility measures: potential measure of injury risk. *J Sports Sci, 32*(13), 1318-1323.

Rago, V., Brito, J., Figueiredo, P., Carvalho, T., Fernandes, T., Fonseca, P., & Rebelo, A. (2018). Countermovement Jump Analysis Using Different Portable Devices: Implications for Field Testing. *Sports (Basel), 6*(3).

Rahnama, N., Lees, A., & Bambaecichi, E. (2005). Comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. *Ergonomics, 48*(11-14), 1568-1575.

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *Int J Sports Med, 28*(3), 228-235.

Sayers, S. P., Harackiewicz, D. V., Harman, E. A., Frykman, P. N., & Rosenstein, M. T. (1999). Cross-validation of three jump power equations. *Med Sci Sports Exerc, 31*(4), 572-577.

Semenick, D. (1990). Test and measurements: The T-test. *Strength & Conditioning Journal, 12*(1), 36-37.
Whiteley, R. (2016). 'Moneyball' and time to be honest about preseason screening: it is a sham making no inroads on the 1 billion dollar injury costs in baseball. *Br J Sports Med, 50*(14), 835-836.

Received: December 10, 2019
Accepted: December 24, 2019
Correspondence to:
Francesca D'Elia
University of Salerno, Italy
E-mail: fdelia@unisa.it