Original Investigation

Physical Characteristics and Strength Ratios Differentiating Starter vs. Non-starter Elite Youth Soccer Players

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ABSTRACT

Background: Soccer players require a plethora of physical capabilities to compete at a higher level. It would be interesting to determine which physical attributes are required for starting players (SP, players chosen in the squad starting the games), and what sets them apart from non-starting players (NSP). **Aim:** 1) to compare physical attributes of SP vs. NSP, and 2) to determine if strength ratios calculated from maximal isometric strength (MIVC) is useful to differentiate between two different groupsof players. **Methods:** Thirty U17 right-leg dominant elite youth soccer players were divided in two groups (starters players [SP; N=15] and non-starters players [SP; N=15]. All players performed a battery of tests: 10m straight-sprint (10 m SS), change of direction (COD), maximal isometric voluntary contraction (MIVC), jumping and dynamic-balance tests. Hamstring to quadriceps ratios (H: Q) and side to side asymmetry werealso calculated from MIVC tests. **Results:** Comparison results showed that SP didbetter in jumping tests (five-jump test [5JT] and broad jump test[BJT] compared to NSP. SP were also able to exert more isometric strength when compared to NSP. SP were faster and presented a better COD ability than NSP. However,no significant differences between the two groups in dynamic-balance ability. Agreater H: Q asymmetry was observedamong NSP compared to SP. **Conclusions:** Youth elite SP's may be distinguished from NSP's through higher isometric strength, jumping, speed and COD tests. Thus, coaches can use theses field tests for designing specific training programs for substitute players to reach a higher level of soccer play.

Keywords: Ratios, soccer, isometric strength, balance, change of direction

INTRODUCTION

In order to perform at high-level within professional elite soccer, it is important that players have adequate lower body strength, linear sprint ability and the capacity to perform explosive, quick change of direction (COD) movements.[1] These key physical capabilities make up the profile of the modern successful soccer players.[29] Recent research suggest how duringsoccer match-play, elite professional players perform more than 220 high-speed runs[21] withapproximately 720 CODswithboth the left and right side.[3] Furthermore, it has been reported that dynamicbalance ability is primordial in order to avoid imbalance since soccer actions are oftenperformed unilaterally (i.e. kicking, jumping and crossing).[10] When discussing the physical

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qualities of soccer players across many levels of play, a greaterrate of lower limb muscle strength and power is required to perform high speed, explosive and decisive match actions (i.e. jumping, talking and sprinting).[13,35] For example, the quadriceps musclesare utilizedconcentrically when passing, kicking or jumping, whereas, hamstring muscles are eccentrically usedwhen performing decelerations and CODs but work concentrically in sprintactions.[22,24] consequently, imbalances between these two muscle groups may lead to an increased risk of hamstring and/or anterior cruciate ligament (ACL) injuries.[32] Hamstring to quadriceps (H: Q) and side to side asymmetry ratios are often screened to determine strength asymmetries.[4] These ratios are subsequently calculated via maximal isokinetic assessment via laboratory dynamometers which are generally of limited access.[6] Subsequently, the use of handheld dynamometers (HHD) may be proposed asa solution for a filed use. To date however, no studies regarding the usefulness of maximal isometric strength replacing the useof isokinetic strength in order to calculate strength ratios have been reported.

In order to determine the physical characteristics of soccer players, many researchers have described use of video analysis and computer software programs,[12] however, many studies compared the fitness performance of high level players to sub-elite population.[14,16,20,23] For example, Gabbett, et al.[14] has recently compared speed, COD capacity and reactive agility between elite vs. sub-elite rugby league players. It was revealed that elite players had superior sprint qualities and quicker decision reactive timesvs. sub-elite players. In addition, Mohamed, et al.[20] utilized the*EUROFIT*battery and specific fitness assessment tests to compare between elite and sub-elite youth handball players. Findings highlighted how elite players scored significantly better on strength, speed and agility but no difference was shown with balance capability.

Specifically within soccer, recent literature has provided analysis concerning the strength and speed characteristics of elite, sub-elite and recreational youth players.[16] Results have shown that the elite group presented significantly higher isometric strength, vertical jump height and short-sprint performancesin comparison with sub-elite groups.This is in-line with similar studies reporting greater strength and strength ratios in elite soccer players compared to sub-elite players.[6] As suggested by Young, et al.[36], care should be taken when comparing between elite vs. sub-elite players especially when the level of play between players is substantial. In this case, differences are likely, and it may be tempting to overstate the importance of a fitness quality to achieve success at the elite level. In this context, in order to minimizethe effect of bias it is wise to compare physical qualities of players from the same squad.

The multi-skilled and multi-demanding physical aspect anddimension of elite soccer raises the question of what physical attributes differentiate between SP and NSP. This is of great significance when trying to improve physical qualities among substitute players. Responding to this question may provide both technical staff andindividuals involved with the physical preparation of players, greater insight into the physical demands placed on youth soccer players. To the authors' knowledge, no current studies have compared the physical qualities and strength ratios between SP vs. NSP of elite youth soccer players. Furthermore, there are no studies regarding the usefulness of strength ratios calculated from maximal isometric voluntary contraction using the handheld dynamometer instead of isokinetic strength. As a result, the aim of the present study was two-fold 1) to compare physical attributes of SP vs. NSP, and 2) to determinate if strength ratios calculated from MIVC is useful to compare between two different levels of players.

MATERIALS AND METHODS

Participants

Thirty (U17)elite youth soccer players selected from a large playing list of the same team participated in the study (table 1).

Players were selected based on six inclusion/exclusion criteria:

1- They were trained subjects.
2- Injured players who were unavailable for selection were excluded.

Table 1: Anthropometrical characteristics of SP vs. NSP

Variables	Starters (n=15)	Non-starters (n=15)
Age (y)	16.78±0.35	16.52±0.23
Height (cm)	173±4.2	174±3.5
Body mass (kg)	67.14±5.12	65.74±6.22
Leg-length (cm)	93.56±5.63	94.90±4.39

3- Goalkeepers were excluded from the study.
4- Only players who had between 16 and 17 years old at the beginning of the study were involved.
5- Players who performed an extra-training were excluded.
6- Selected players had had at least 5 years of soccer practice within the 1st Division of the national youth soccer league

Players were divided into two groups (starters vs. non-starters) according to their playing time, where Substitute players were chosen from those who played at least 10-min per game. All tests were administered during the competition phase (3rd month of the season), where their training schedule consisted of approximately five training sessions and one official game per-week. Before data collection, all participants were informed about the aim and the potential risks of the study. The study was conducted according to the declaration of Helsinki and the protocol was approved by the institutional ethics committee. All participants and their parents/guardians reviewed and signed written informed consents.

Design

Testing sessions were carried out on a 3rd generation synthetic soccer turf in the morning between 9 am and 11am, where the temperature and humidity were of 16°C and 70% respectively. To ensure a good adherence to the pitch, players were asked to wear adapted molded plastic soccer boots throughout the testing sessions. All players performed at least two familiarization sessions before starting with tests.During the 48 hours preceding testing, players refrained from heavy training and maintained their usual daily training (technical and tactical training). Before performing tests, 10-min of standardized warm-up, excluding static stretching was administered for all participants.Isometric strength tests were carried out in a clinical examination room by an experimented physiotherapist.

10 m Straight-Sprint Test (10 m SS)

The test consisted of sprinting as fast as possible over a distance of 10mas between the starting and the finishing lines. The test started with players positioned in a standing position with their preferred foot forward and behind the starting line. The total time was recorded using photocell gates (Brower Timing Systems, Salt Lake City, UT; accuracy of 0.01 s) with gates located at a height of 0.5 m from the ground and spaced by 1 m. The fastest timed sprint performance was used in the present study.

Jumping Tests

All players performed three jumping tests: 1) the 5JT which consisted of covering the greatest horizontal distance possible by achieving five alternate leg jumps. Players started and finished the test in a standing position with their feet parallel. A fixed measuring tape was used to measure the horizontal jumping performance (from the front part of the player's feet at the starting position to the rear part of the feet at the final landing position). The best 5JT performance was expressed relative to leg length and used for statistical analysis. 2) The triple hop-jump test consisted of performing three consecutive maximal horizontal jumps with the same leg and using an arm swing. Players started in a standing position on the designed testing leg, with their big toe on the starting line. The performance was measured with a fixed measuring tape from the starting line to rear edge of the heel after completing the third hop and the best performance was recorded for analysis. 3) The standing broad-jump test started with players in a standing position with their feet parallel and shoulder-width apart behind a starting line. The test consisted of jumping forward as far as possible with both feet simultaneously with the possibility of using an arm swing. The total performance was assessed from the starting line to the rear edge of the heel after completing the jump via a fixed measuring tape.

Modified Illinois Change of Direction Test

The MICODT were performed with players starting in a standing position, with their preferred foot forward and placed 0.5 m behind the starting line. The test involves players to sprint and changing direction as fast as possible from point A to point B as indicated in Figure 1. Test's performance was measured via two timing gates (Brower Timing Systems, Salt Lake City, UT; accuracy of 0.01 second) placed at the start and at the finish lines. The test were performed twice with three minutes of rest in between and the best performance (shortest time) was used for statistical analysis. During the test, participants did not receive any technical advice in relation with the technique of changing direction.

Maximal Isometric Voluntary Contraction Test

MIVC was measured using a valid and reliable portable dynamometer (Microfet 2, Hoggan Health Industries, Inc., Draper, UT).[9,11] Maximal isometric strength of the

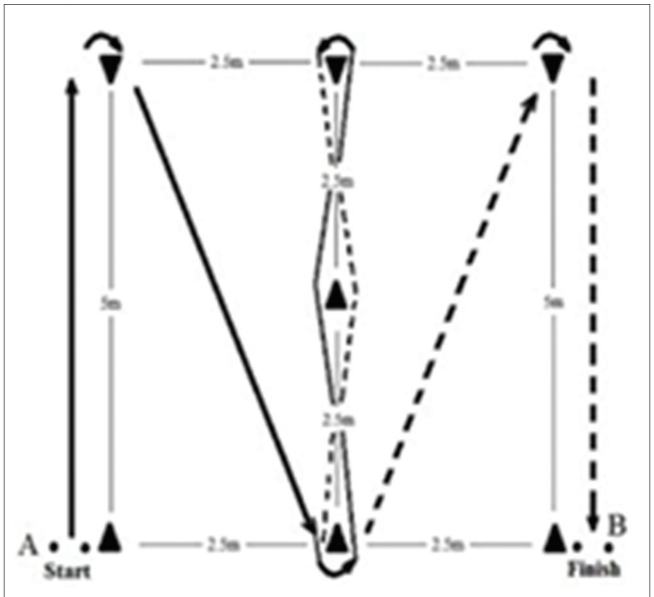

Figure 1: Diagram of the modified illinois change of direction test

knee flexors/extensors was measured twice on each side of the body. The test started when the examiner applied resistance in a fixed position and the player exerted 5 s of maximal isometric force against the dynamometer. The participants were told to stabilize themselves by holding on to the sides of the table with their hands. All MIVC test were performed according to procedures applied in clinical settings.[5,34] Maximal isometric strength was measured in a sitting position with the dynamometer placed on the posterior aspect of the calcaneus for the knee flexors and placed perpendicular to the anterior aspect of the tibia, 5 cm proximal of the medial malleolus for the knee extensors.[28] All tests were administered twice and the best performance (high value of strength) was recorded for analysis. Two minutes of rest were allowed between trials in order to avoid a decline of strength. Performance was assessed via a handheld dynamometer (Microfet 2, Hoggan Health Industries, Inc., Draper, UT) and has been expressed as absolute (N) and allometrically scaled (N·kg−0.67) values.[7]

Star Excursion Balance Test (SEBT)

Balance was investigated using the Star Excursion Balance Test (SEBT). SEBT assesses dynamic single leg balance while reaching in 8 reach directions based on the orientation of the stance limb: namely, anterior, posterior, medial, lateral, anterior lateral, anterior medial, posterior lateral, and posterior medial.[8] The SEBT is performed by placing strips of tape on the floor in a grid format while the participant stands in the middle of the grid and reaches as far as possible in one reach direction touching down lightly so the researcher can mark and subsequently measure the reached distance. Trials are considered successful when there is no movement in the stance limb during the SEBT, controlled motion while maintaining balance, and returning of the reaching limb back to the starting point.Sincereach distance is related to limblength, it was normalizedto limb length by dividing the reach distance by limb length then multiplied by 100.[27] In order to compare SP vs. NSP, a global index of balance was calculated (composite score). The composite score was the sum of eight reach distance divided by eight times limb length, and then multiplied by 100.[27]

Strength Ratios

Isometric strength ratios were calculated as calculated from maximal isokinetic strength.[32] The H:Q ratio was calculated by dividing the hamstrings isometric strength by Quadriceps isometric strength. The side to side strength asymmetry was calculated as follows: ((isometric strength of the stronger leg - isometric strength of the weaker leg)/isometric strength of the weaker leg)*100.

Statistical Analysis

Statistical analyses were performed using SPSS software statistical package (SPSS Inc., Chicago, IL, version. 18.0). All variables were shown as mean ± SD. Preliminary assumption testing was conducted to check for normality, linearity, and multicollinearity. Independent t-test (s) were used to compare physical tests between starter and non-starter players, and statistical significance was set at $p<0.05$.

Table 2: Isometric strength and lower limb power test of starter vs. non-starter players

Variable	SP	NSP	P -value
Relative 5JT (m)	2.46±0.20	2.33±0.14	0.04
THJ-DL (m)	6.20±0.68	6.10±0.44	0.54
THJ-NDL (m)	6.31±0.57	6.14±0.41	0.36
BJT (m)	2.22±0.14	2.12±0.12	0.03
Knee flexors DL ($N.kg^{-0.67}$)	16.89±3.08	14.92±1.92	0.04
Knee flexors NDL ($N.kg^{-0.67}$)	15.99±2.79	13.86±1.84	0.02
Knee extensors DL ($N.kg^{-0.67}$)	35.39±3.12	33.05±2.73	0.03
Knee extensors NDL ($N.kg^{-0.67}$)	31.60±4.77	32.23±4.03	0.70

SP: starter-players; NSP: non-starter players; 5JT: five-jump test; THJ: triple-hop jump; BJT: broad-jump test; DL: dominant leg; NDL: non-dominant leg

Table 3: Straight sprint, change of direction and balance tests of starter vs. non-starter players

Variable	SP	NSP	P -value
10 m SS (s)	1.79±0.07	1.86±0.08	0.03
MICODT (m)	11.57±0.46	12.07±0.51	0.007
SEBT			
Composite score with DL (%)	99.32±6.99	99.37±10.07	0.99
Composite score with NDL(%)	96.84±8.99	96.68±9.49	0.96

SS: straight-sprint; MICODT: modified Illinois change of direction test; SEBT: start excursion balance test

Table 4: Isometric lower limb strength ratios of starter vs. non-starter players

Variable	SP	NSP	P -value
H:Q isometric strength ratios			
Dominant leg	0.48±0.09	0.54±0.07	0.48
Non-dominant leg	0.51±0.11	0.44±0.08	0.04
Side to side asymmetry			
Hamstring (%)	5.98±9.90	8.06±9.04	0.55
Quadriceps (%)	7.54±12.81	3.28±8.10	0.28

H: hamstring; Q: Quadriceps.

RESULTS

Comparison results of explosive and isometric strength tests are summarized in table 2. Statistical analysis showed that SP's were better in 5JT and BJT tests when compared to NSP. However, no significant difference between SP and NSPin THJ tests with DL and NDL. Furthermore, the present study showed that SP's were able to exert more isometric strength (knee flexion and extension) with the DL and NDL when compared to NSP. There were no significant differences between the two groups in the SBET composite score. However, SP were faster (10mSS) and presented a better COD ability than NSP (table 3). Analysis of isometric strength ratios reveled greater H: Q asymmetry among NSP compared to SP (table 4).

DISCUSSION

The purpose of the present study was to compare a range of physical attributes between starters and non-starters eliteyouth soccer players with the aim of characterizing this population and highlight limiting performance measures. The novelty of this specific studywas the comparison between SP and NSP from the same squad. Results demonstrate that SP have better straight-sprint, change of direction, lower limb isometric strength and jump performance (relative 5JT) than NSP, suggesting that these physical qualities may contribute to the higher playing standard of elite young elite players.

The results of the present study were in accordance with previous studies performed in team sport. Indeed,Gabbett, et al.[15] reported that rugby SP had greater speed, COD and jump performance compared to NSP. Moreover,Young, et al.[36] showed that AFL SP presented better leg power and linear sprinting performance when compared to NSP. In the present study, the difference in speed, COD and jumping performance between SP and NSP highlight the importance of these physical attributes in a high level of soccer competition.

Soccer requires maintaining unilateral balance when executing movement with the contralateral leg (i.e. kicking, jumping, and crossing the ball).[31] It has been reported that dynamic balance requires standing whilst maintaining isometric posture of lower limb muscles. Chtara, et al.[10] reported a significant positive relationship between isometric strength (DL and NDL) and dynamic balance ability (y-balance test), whereas a stepwise multiple regression analysis of the study also showed that maximal isometric strength explained between 21.9% and 49.4% of the variance of the Y-balance test. Despite the importance of dynamic balance in soccer, the present study reported no significant difference in dynamic balance ability between SP vs. NSP. Thus indicates that balance ability is not a discriminative quality between two levels of players from the same squad. To our knowledge, this is the first study comparing balance ability of players from the same squad, and as a result it can be suggested that the non-significant difference in balance between SP and NSP may be explained by the similarities in term of training program (strength training) and training load between the two groups. Indeed, it has been indicated that professional soccer players had better balance ability compared to amateur players[25,26] due to the difference in the levels of expertise and the training program and intensity between professional and amateur players.

Isometric tests are used to assess the force-producing capacity of the neuromuscular system.[17] Lower limb isometric strength is often measured via the Biodex system dynamometer which provides a high reliability and represents the gold standard. However, this machine is very costly and not portable for a filed use. Thus, the novel aspect of the present study is the comparison of isometric strength in SP vs. NSP young soccer players via a hand-held dynamometer. This dynamometer presents a good reliability and accurate assessment among young and adult soccer players.[34] In the present study, SP presented higher lower limb isometric strength compared to NSP (expect Knee extensors of NDL). The results of the present study could be considered similar to those reported by Gissis, et al.[16], indicating significant difference in lower limb isometric strength among three level of young soccer players. However, the present study were not in accordance with the findings of Young, et al.[36] whoreported no significant differencesamongstlower limb strength between SP vs. NSP. We speculate that this difference could be explained by the difference in the study design between the two studies. Indeed, in the present study, isometric lower limb strength has been measuredwith a handheld dynamometer. However, in the Young, et al.[36] study, it has been assessed by isokinetic dynamometry. Moreover, the present study has been conducted among young soccer players while the study of young et al among adult Australian football players. The differences in maximal isometric strength found between SP and NSP in the present study could be attributed to the fact that SP participate in a greater number of weekly soccer game in comparison with NSP, which allow them to perform a high number of high-intensity actions compared to NSP. Indeed, it has been suggested that players who are exposed to increased playing minutes as a result will generally improve their technical and physical capacity compared to players who are substitutes or are not exposed to increased playing time.[33] Unfortunately the training load has not been monitored in the present study. Moreover, lower limb isometric strength is highly related to performance. Indeed, it has been reported that the force produced during the first 100 ms is an important part of the isometric force–time curve because it is the initial development of force, and it represents the ability of the musculoskeletal system to rapidly develop maximal force.[16] Therefore, we speculate that a high level of isometric strength is necessary to reach a high level of play in soccer.

Linear sprinting ability and rapid changing direction are essential components of modern soccer and can distinguish between the levels of play (Elite vs. sub elite).[29] However, to our knowledge, this is the first study that aimed to compare these physical qualities in starters vs. non-starters young soccer players. The present study showed a better 10 m SS performance in SP compared to NSP. These results are consistent with those reported byYoung, et al.[36] who indicated that in AFL, SP had better sprint times than NSP. Moreover, Manson, et al.[19] reported that in female soccer players, SP tended to be faster than NSP. In the same context, the results of the present study indicated a better COD performance among SP compared to NSP.Gabbett, et al.[15] highlighted contrasting reports to the present studyindicating no significant difference in agility performance between starters and non-starters junior rugby players. The difference between our finding and those of Gabbett, et al.[15] may be due to the difference in the participants (rugby players vs. soccer players). Moreover, the COD test suggested by Gabbett, et al.[15] was different from theone used in the present study. Indeed, the 505 test is composed by only one COD of 180°, while the MICODT is composed by multiple cuts at angle less than 180°. It should be noted that having a high level of strength may enhance others motor skills such as jumping, sprinting or changing direction.[1] Thus the better agility and sprinting performance reported by the present study among SP vs.NSP could be explained partly by the significant difference in isometric strength between the two levels of players. Indeed, it has been reported that isometric strength of the lower-limb muscles represented a major determinant factor of sprinting and COD-ability.[30]

Jumping tests are used to assess lower-limb power, and commonly features when testing for talent identification in soccer.[18,29] It has been reported that the force developed by the lower limb extensors and intramuscular coordination and co-activation are the main factors affecting the jumping performance. In a team sports such as the soccer, a high level of power production represents an important factor of success.[2] The results of the current study demonstrated that SP had a better jumping performance (relative 5JT and BJT) than NSP. However, no significant differences in the THJ (DL and NDL) between the two levels of players. The results of the present study are in accordance with many studies. Indeed, Baker 1993 reported a higher vertical jump index among SP vs. NSP. Moreover, Young et al reported a better CMJ and DJ performance among AFL SP when compared to NSP. On the other hand, others studies reported no significant differences in jumping performance between SP vs. NSP from the same squad. For example, it has been reported that starter's junior rugby players had not higher jumping performance than NSP. The difference between the previous study and our results may be explained by the difference in the design of the two studies. Indeed, power tests of the present study are composed by horizontal jumping tests (horizontal and vertical component), while Gabbett, et al.[15] used only a vertical jumping tests to assess lower limb power. Although that soccer players are characterized by a between-legs asymmetries due to unilateral use of the legs (jumping, kicking)[31], the present study showed that unilateral jumping tests (THJ with DL and NDL) did not differentiate between starters and non-starters players.

The assessment of lower limb strength output in soccer is important in order to detect any muscle imbalance. Isokinetic dynamometers are usually used in such context and represent the gold standard of strength measuring. It has been reported that Quadriceps and hamstring muscles are very involved in soccer and that any asymmetries between theses muscles groups increase the risk of injury occurrence. In order to screen for lower limb asymmetries hamstring to quadriceps (H:Q) and side to side asymmetry ratios are calculated via maximal isokinetic assessment through costly laboratory dynamometers which cannot be useful in the field. Despite the fact that previous studies showed that HHD is a reliable instrument and could replace isokinetic dynamometers for a field use, this is the first study that calculated strength ratios from maximal strength measure via a portable dynamometer. The authors of the present study believe that such design needs a scientific validation in a large sample; however, this study could be a pilot one for future investigations. The present study showed no significant difference in Side to side asymmetry ratios (hamstring and quadriceps) between SP vs. NSP. However, H:Q isometric strength ratio of the NDL revealed a lower value among NSP compared to SP indicating a high risk of lower limb injury in NSP. Indeed it has been reported that the lower the H:Q ratio the higher the risk of knee injury.

The main limitation of the present study was the not assessing of maximal aerobic performance via a field test. Also, measuring only maximal isometric strength and power of limbs may be the second limit of the present study. Future studies should take into consideration maximal strength (1RM) when comparing SP vs. NSP. Linear sprinting ability was measured only via a 10 m SS test while 20 m and 30 m sprinting ability are also determinant factors of success in soccer. Finally, futures investigations should perform such analysis in a higher number of participants in order to draw a more general conclusion.

Practical Application

The present study showed that strength, speed and change of direction abilities could differentiate between two levels of players from the same squad suggesting that these physical qualities may provide useful information for attaining high soccer level. Thus, coaches and physical trainers can use theses field tests for designing specific training programs for substitute players to reach a higher level of soccer play.

CONCLUSION

In conclusion, the findings of the present study suggest that youth elite SP'smay be distinguished from NSP'sthroughlower isometric strength measured by a handheld dynamometer, jumping, speed and COD capabilities. Furthermore, dynamic balance ability does not seem to be a discriminating factor of success in elite youth soccer.

REFERENCES

1. M. Barker, T. J. Wyatt, R. L. Johnson, M. H. Stone, H. S. O'Bryant, C. Poe, and M. Kent. Performance Factors, Psychological Assessment, Physical Characteristics, and Football Playing Ability. *Journal of Strength & Conditioning Research*. 7 (1993), 224-33.
2. J. Bencke, R. Damsgaard, A. Saekmose, P. Jorgensen, K. Jorgensen, and K. Klausen. Anaerobic Power and Muscle Strength Characteristics of 11 Years Old Elite and Non-Elite Boys and Girls from Gymnastics, Team Handball, Tennis and Swimming. *Scand J Med Sci Sports*. 12 (2002), 171-8.
3. J. Bloomfield, R. Polman, and P. O'Donoghue. Physical Demands of Different Positions in Fa Premier League Soccer. *J Sports Sci Med*. 6 (2007), 63-70.
4. S. R. Brown, M. Brughelli, P. C. Griffiths, and J. B. Cronin. Lower-Extremity Isokinetic Strength Profiling in Professional Rugby League and Rugby Union. *Int J Sports Physiol Perform*. 9 (2014), 358-61.
5. M. Carroll, W. Joyce, A. Brenton-Rule, N. Dalbeth, and K. Rome. Assessment of Foot and Ankle Muscle Strength Using Hand Held Dynamometry in Patients with Established Rheumatoid Arthritis. *J Foot Ankle Res*. 6 (2013), 10.
6. A. Carvalho, S. Brown, and E. Abade. Evaluating Injury Risk in First and Second League Professional Portuguese Soccer: Muscular Strength and Asymmetry. *J Hum Kinet*. 51 (2016), 19-26.
7. K. Chamari, Y. Hachana, Y. B. Ahmed, O. Galy, F. Sghaier, J. C. Chatard, O. Hue, and U. Wisloff. Field and Laboratory Testing in Young Elite Soccer Players. *Br J Sports Med*. 38 (2004), 191-6.
8. N. J. Chimera, and M. Warren. Use of Clinical Movement Screening Tests to Predict Injury in Sport. *World J Orthop*. 7 (2016), 202-17.
9. S. P. Chrisman, J. W. O'Kane, N. L. Polissar, A. F. Tencer, C. D. Mack, M. R. Levy, and M. A. Schiff. Strength and Jump Biomechanics of Elite and Recreational Female Youth Soccer Players. *J Athl Train*. 47 (2012), 609-15.

10. M. Chtara, M. Rouissi, N. L. Bragazzi, A. L. Owen, M. Haddad, and K. Chamari. Dynamic Balance Ability in Young Elite Soccer Players: Implication of Isometric Strength. *J Sports Med Phys Fitness*. (2016).
11. J. F. Crow, A. J. Pearce, J. P. Veale, D. VanderWesthuizen, P. T. Coburn, and T. Pizzari. Hip Adductor Muscle Strength Is Reduced Preceding and During the Onset of Groin Pain in Elite Junior Australian Football Players. *J Sci Med Sport*. 13 (2010), 202-4.
12. B. Dawson, R. Hopkinson, B. Appleby, G. Stewart, and C. Roberts. Player Movement Patterns and Game Activities in the Australian Football League. *J Sci Med Sport*. 7 (2004), 278-91.
13. N. Eniseler, C. Sahan, H. Vurgun, and H. F. Mavi. Isokinetic Strength Responses to Season-Long Training and Competition in Turkish Elite Soccer Players. *J Hum Kinet*. 31 (2012), 159-68.
14. T. J. Gabbett, J. N. Kelly, and J. M. Sheppard. Speed, Change of Direction Speed, and Reactive Agility of Rugby League Players. *J Strength Cond Res*. 22 (2008), 174-81.
15. T. Gabbett, J. Kelly, S. Ralph, and D. Driscoll. Physiological and Anthropometric Characteristics of Junior Elite and Sub-Elite Rugby League Players, with Special Reference to Starters and Non-Starters. *J Sci Med Sport*. 12 (2009), 215-22.
16. I. Gissis, C. Papadopoulos, V. I. Kalapotharakos, A. Sotiropoulos, G. Komsis, and E. Manolopoulos. Strength and Speed Characteristics of Elite, Subelite, and Recreational Young Soccer Players. *Res Sports Med*. 14 (2006), 205-14.
17. K. Hakkinen. Neuromuscular Fatigue and Recovery in Male and Female Athletes During Heavy Resistance Exercise. *Int J Sports Med*. 14 (1993), 53-9.
18. F. le Gall, C. Carling, M. Williams, and T. Reilly. Anthropometric and Fitness Characteristics of International, Professional and Amateur Male Graduate Soccer Players from an Elite Youth Academy. *J Sci Med Sport*. 13 (2010), 90-5.
19. S. A. Manson, M. Brughelli, and N. K. Harris. Physiological Characteristics of International Female Soccer Players. *J Strength Cond Res*. 28 (2014), 308-18.
20. H. Mohamed, R. Vaeyens, S. Matthys, M. Multael, J. Lefevre, M. Lenoir, and R. Philppaerts. Anthropometric and Performance Measures for the Development of a Talent Detection and Identification Model in Youth Handball. *J Sports Sci*. 27 (2009), 257-66.
21. M. Mohr, P. Krustrup, and J. Bangsbo. Match Performance of High-Standard Soccer Players with Special Reference to Development of Fatigue. *J Sports Sci*. 21 (2003), 519-28.
22. R. R. Neptune, I. C. Wright, and A. J. van den Bogert. Muscle Coordination and Function During Cutting Movements. *Med Sci Sports Exerc*. 31 (1999), 294-302.
23. C. H. Ooi, A. Tan, A. Ahmad, K. W. Kwong, R. Sompong, K. A. Ghazali, S. L. Liew, W. J. Chai, and M. W. Thompson. Physiological Characteristics of Elite and Sub-Elite Badminton Players. *J Sports Sci*. 27 (2009), 1591-9.
24. D. A. Opar, and B. G. Serpell. Is There a Potential Relationship between Prior Hamstring Strain Injury and Increased Risk for Future Anterior Cruciate Ligament Injury? *Arch Phys Med Rehabil*. 95 (2014), 401-5.
25. T. Paillard, and F. Noe. Effect of Expertise and Visual Contribution on Postural Control in Soccer. *Scand J Med Sci Sports*. 16 (2006), 345-8.
26. T. Paillard, F. Noe, T. Riviere, V. Marion, R. Montoya, and P. Dupui. Postural Performance and Strategy in the Unipedal Stance of Soccer Players at Different Levels of Competition. *J Athl Train*. 41 (2006), 172-6.
27. P. J. Plisky, P. P. Gorman, R. J. Butler, K. B. Kiesel, F. B. Underwood, and B. Elkins. The Reliability of an Instrumented Device for Measuring Components of the Star Excursion Balance Test. *N Am J Sports Phys Ther*. 4 (2009), 92-9.
28. Y. H. Pua, T. V. Wrigley, S. M. Cowan, and K. L. Bennell. Intrarater Test-Retest Reliability of Hip Range of Motion and Hip Muscle Strength Measurements in Persons with Hip Osteoarthritis. *Arch Phys Med Rehabil*. 89 (2008), 1146-54.
29. T. Reilly, J. Bangsbo, and A. Franks. Anthropometric and Physiological Predispositions for Elite Soccer. *J Sports Sci*. 18 (2000), 669-83.
30. M. Rouissi, M. Chtara, A. Owen, A. Burnett, and K. Chamari. Change of Direction Ability in Young Elite Soccer Players: Determining Factors Vary with Angle Variation. *J Sports Med Phys Fitness*. (2016).
31. M. Rouissi, M. Chtara, A. Owen, A. Chaalali, A. Chaouachi, T. Gabbett, and K. Chamari. Effect of Leg Dominance on Change of Direction Ability Amongst Young Elite Soccer Players. *J Sports Sci*. 34 (2016), 542-8.
32. C. V. Ruas, F. Minozzo, M. D. Pinto, L. E. Brown, and R. S. Pinto. Lower-Extremity Strength Ratios of Professional Soccer Players According to Field Position. *J Strength Cond Res*. 29 (2015), 1220-6.
33. J. R. Silva, J. F. Magalhaes, A. A. Ascensao, E. M. Oliveira, A. F. Seabra, and A. N. Rebelo. Individual Match Playing Time During the Season Affects Fitness-Related Parameters of Male Professional Soccer Players. *J Strength Cond Res*. 25 (2011), 2729-39.
34. K. Thorborg, C. Couppe, J. Petersen, S. P. Magnusson, and P. Holmich. Eccentric Hip Adduction and Abduction Strength in Elite Soccer Players and Matched Controls: A Cross-Sectional Study. *Br J Sports Med*. 45 (2011), 10-3.
35. U. Wisloff, C. Castagna, J. Helgerud, R. Jones, and J. Hoff. Strong Correlation of Maximal Squat Strength with Sprint Performance and Vertical Jump Height in Elite Soccer Players. *Br J Sports Med*. 38 (2004), 285-8.
36. W. B. Young, R. U. Newton, T. L. Doyle, D. Chapman, S. Cormack, G. Stewart, and B. Dawson. Physiological and Anthropometric Characteristics of Starters and Non-Starters and Playing Positions in Elite Australian Rules Football: A Case Study. *J Sci Med Sport*. 8 (2005), 333-45.