TAKE-OFF AND LANDING PROPERTIES IN TOP-LEVEL FOOTBALL PLAYERS: A GROUND REACTION FORCE STUDY

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Original scientific paper
UDC 577.3:796.332

Abstract:

The aims of the research presented here are to contribute to a better understanding of the neuromuscular basis of football movement patterns and allow its findings to be applied by athletes and their coaches to improve athletic performance. This paper explores explosive power, i.e. the type of force that is present in almost all segments of a football game and is basic for almost all individual skills (dribbling, shooting, heading, shielding, intercepting...), basic movements (e.g. running, changing direction, turning, stopping, dribbling, jumping) and depends on the following physiological qualities: e.g. strength, speed, agility. As a criterion for testing explosive power, the registered ground reaction forces in performing the counter movement vertical jump are analysed, both in performance with one and with both legs. The obtained results have yielded statistically significant variation in force variables, which means that a similar test could be applied to a larger number of examinees with greater reliability. The test can be carried out at any point during the training process as an additional indication of preparedness benefiting both the coach and the athletes themselves.

Key words: *football, explosive power, vertical jump tests*

DIE CHARAKTERISTIKEN DES ABSPRUNGS UND DER LANDUNG BEI SPITZENFUßBALLSPIELERN: FORSCHUNG DER BODENREAKTIONSKRAFT

Zusammensetzung:

Das Ziel dieser Forschung war, zur besseren Wahrnehmung von neuromuskulärer Basis der fußballspezifischen Bewegungsschema beizutragen und zu ermöglichen, dass die Ergebnisse dieser Forschung von Sportlern und Trainern dazu verwendet werden, sportliche Leistung zu verbessern. Dieser Artikel erforscht Explosivkraft, d.h. den Typ der Kraft, die in fast allen Segmenten eines Fußballmatches anwesend ist und die fast alle individuelle Fertigkeiten (Dribbeln, Schießen, Kopfstößen, Deckung, Abfangen usw.), basische Bewegungen (z. B. Laufen, Richtungsänderung, Drehen, Stoppen, Dribbeln, Springen) und physiologische Merkmale (z. B. Kraft, Geschwindigkeit, Gewandtheit) in einem Fußballmatch umfasst. Als das Kriterium für die Explosivkraftmessung wurden die registrierten Bodenreaktionskräfte sowohl während des einbeinigen als auch während des beidbeinigen Gegenbewegungsvertikalsprungs analysiert. Statistisch bearbeitete Variablen der Kraft brachten statistisch bedeutende Variation hervor. Das heißt, dass ein ähnlicher Test an höherer Anzahl von Probanden mit größerer Zuverlässigkeit angewandt werden könnte. Der Test, von dem sowohl der Trainer als auch die Sportler profitieren können, kann in jedem Zeitpunkt während des Trainingsprozesses durchgeführt werden als ein zusätzlicher Indikator des Vorbereitungsniveaus.

Schlüsselwörter: *Fußball, Explosivkraft, Vertikalsprung*

Introduction

Successful performance in football as a modern game depends on many important factors and skills. To better understand the game of football as a sport activity, we should remind ourselves of some of its general characteristics. In a top level football match, 900-1000 actions with the ball are executed, 350 passes with one touch, 150 with two touches and the rest with several touches and after dribbling the ball. Successful top teams need an average of 16-30 attacks and 7-10 shots to score one goal. The attacks that produce a goal take less

than 25 seconds. Two to six players take part in these attacks and one to six passes are needed to score one goal. The distance covered and the type of movement by players in football depend on the player's position and role in the game (Luhtanen, 1994). The players performed an average of 96 sprints ranging from 1.5m - 105m. The time for low and high-intensity work averaged 51.6 sec and 3.7 sec, respectively. The matches included tackles (51.4), turns (49.9) and jumps (9.4) (Withers et al., 1982). Table 1 provides a summary of the work rate of a top class player per match and per training session (individual training has not been taken into account in this summary). A biomechanical approach can be used to define the characteristics of skills, to gain an understanding of the mechanical effectiveness of their execution and to identify the factors underlying a player's successful performance. The purpose of the research presented is to contribute to a better understanding of the neuromuscular basis of football movement patterns and allow its findings to be applied by athletes and their coaches to improve athletic performance. In this biomechanical research we review some important factors in play, individual skills, and basic movements in football (Figure 1). One of the most important factors for successful performance in football is explosive strength or power of the lower extremities. Football is a game of short, intense bouts of speed, explosive power and change of direction. This paper explores explosive power, i.e. the type of force that is present in almost all segments of a football game and includes almost all individual skills (dribbling, shooting, heading, shielding, intercepting...), basic movements (e.g. running, changing direction, turning, stopping, dribbling, jumping) and physiological qualities (e.g. strength, speed, agility) in a football game. (Luhtanen, 1994).

Table 1. An evaluation of the work rate in match and training conditions per season (Withers et al, 1982).

Motion mode	Work rate in matches		Work rate in training		Total work rate	
	Match	Season	Training	Season	Total season	Steps Approx.
	Dist. (km)	Dist. (km)	Dist. (km)	Dist. (km)	Dist. (km)	Number
Walking	3	180	2	440	620	890000
Jogging	5	300	4	880	1180	980000
Striding	1.5	90	3	660	750	420000
Sprinting	0.7	42	1.5	330	372	190000
Other	1	60	1.5	330	390	400000
Total	11.2	672	12	2640	3312	3000000
With ball	0.2	12	0.4	88	100	

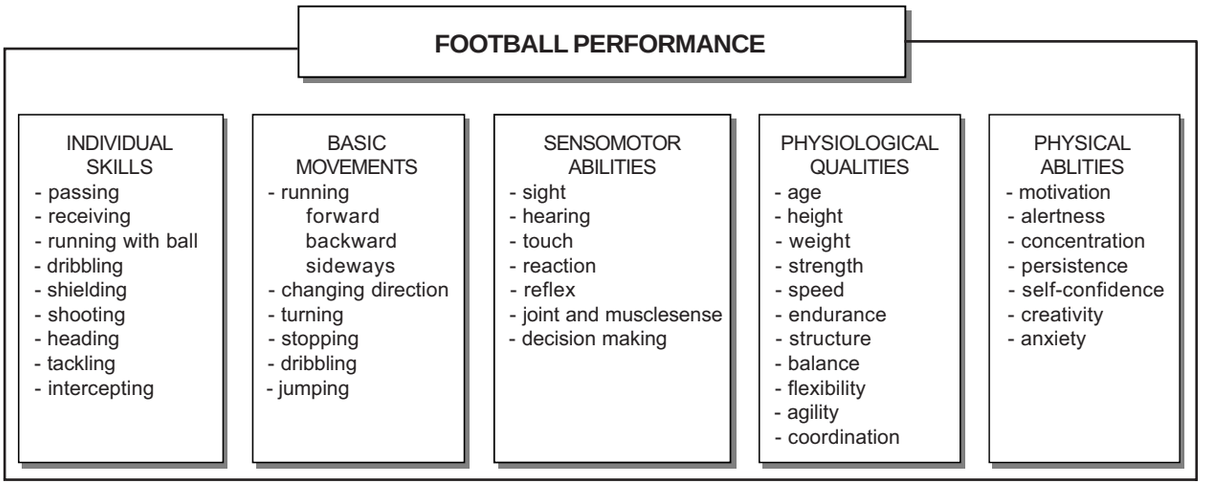

Figure 1. Various factors influencing individual skills in football (Withers et al, 1982).

Depending on the player's position and role in the game, that power is focused in different areas.

In goalkeepers, the explosive power is manifested in the goalkeeper's ability to:
- more efficiently change direction in the goal area,
- react to the ball off the foot of a shot,
- cover and defend a larger part of the goal area,
- put himself in a position to make saves,
- better recover from a misjudged shot.

In defenders, the explosive power is manifested in their ability to:
- better recover on defence,
- efficiently change direction in a one-on-one situation,
- jump up and head the ball away from a would-be attacker,
- fight off an opposing player.

In midfielders, the explosive power is manifested in their ability to:
- win the ball before an opposing player does,
- increase strength and power on long balls and shots,
- more efficiently switch from offence to defence,
- jump higher and win the ball in the air,
- beat an opposing player.

In forwards, the explosive power is manifested in their ability to:
- fight off an opposing player (defender),
- shoot at the goal,
- outrun a defender and create a one-on-one situation with the goalkeeper,
- efficiently change direction with the ball.

Explosive power is defined as the maximal power that can be produced by a muscle or a group of muscles in the shortest possible time. In explosive power of the lower extremities, the dominant role is exercised by: the extensor of the lower leg (*m. quadriceps*), the flexor of the lower leg (*m. biceps femoris*) and the extensor of the foot (*m. soleus*). Out of the wide range of skills involved in a player's performance in football only football kicks have been the real subject of detailed biomechanical analysis. Some skills and basic movements such as jumping, running, sprinting, starting, stopping and changing direction have not been the subject of detailed biomechanical analysis at all. Previous investigations have shown a significant connection between the results of vertical jump tests and the explosive power of the lower extremities (Kasović & Medved, 1998). Most referenced and investigated tests for estimating explosive power involve the Counter Movement Jump (CMJ) and Sargent's test. The reliability of these tests has been confirmed at 0.93, with a reliability coefficient of 0.78 (according to Maneval & Poole 1987, in swimmers). There are several factors influencing the capacity of an athlete to perform a vertical jump. Komi (according to Koneko et al., 1983) considers that a specific muscle structure of an athlete plays an important role in the development and reproduction of explosive power. Athletes with a higher percentage of "white" skeletal muscle fibres have a greater possibility of generating and demonstrating explosive power. White skeletal muscle fibres are thicker than the red ones, contain more myofibrils but less myoglobin and mitochondria, contract faster but are not enduring. The red skeletal muscle fibres, in contrast to the white ones, contain a large amount of myoglobin and mitochondria, contract slowly but are enduring. This theory is accepted by numerous other investigators. Wilson et al. (1993), as well as Sale (1988) list several neurophysiological phenomena that can reflect upon muscle strength. They include the number of activated motor units, the synchronisation of motor units and the specificity of performing a particular movement. Schmidtbleicher (Young et al, 1995) mentions that the technique applied by some athletes (e.g. in basketball and volleyball) also plays an important role in developing explosive power. Such athletes demonstrate a better utilization of elastic energy stored in a muscle for performing a dynamic contraction indispensable in maximal explosive power. Linthorne has shown in his article (Linthorne, 2001) how a force platform analysis of the standing vertical jump may be used in teaching the kinematics and dynamics of a one-dimensional motion. He uses computer software that produces curves of velocity and displacement of the jumper's center of mass by a numerical integration of the force–time record from a force platform. A simultaneous examination of these curves vividly illustrates the relations between the forces acting on a body and the resulting acceleration, velocity, and displacement of the body. Authors (Row & Hreljac, 2000) have found in their research that one-legged and two-legged vertical jumps do not differ in jump height in a group of athletes accustomed to their use. The two-legged jump results in greater impulses and forces, and the one-legged jump utilizes a higher take-off height (Vint & Hinrichs, 1996) and potentially benefits from increased muscle stiffness on impact. Other factors important in performing the vertical jump as an indicator of explosive force include: arms swing, timely trunk extension and head movement, strength of the upper extremities and trunk strength. The aim of this paper is to contribute to the understanding of the most effective way of performing the

particular movement structures in a football game by investigating the biomechanical patterns. As a criterion for testing explosive power, the registered ground reaction forces in performing the counter-movement vertical jump (Figure 2) are analysed, both in performance with one and with both legs. We first investigated such markers with regard to the role and position of a player in a top team. Then we tried to establish whether there were differences in the performance of the vertical jump with one leg in comparison to doing it with both legs. The paper tries to give a better insight into the very problems of a football game and to ensure a larger quantity of relevant information for coaches in managing the training process, which could potentially lead to significant improvements in related sport results.

ment in the opposite direction. The muscles are said to be "pre-stretched" before shortening in the desired direction.

H_1 - The means of the force variables for the groups of the forwards and midfield players are significantly different.

H_2 - The means of the force variables for the groups of the defenders and forwards are significantly different.

H_3 - The means of the force variables for the groups of the midfield players and defenders are significantly different.

Figure 2. Testing of take-off and landing capacities force

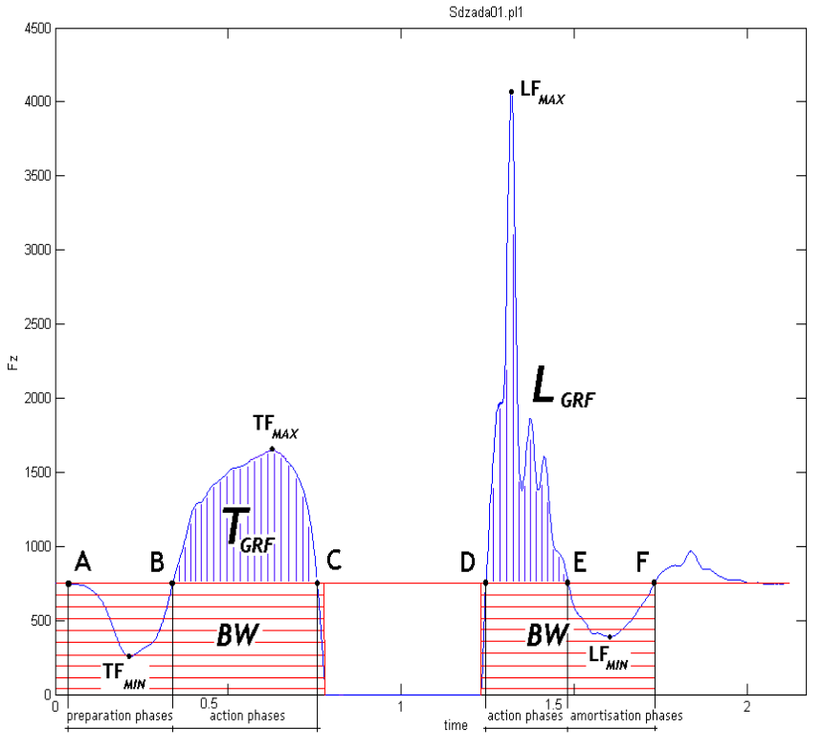

Figure 3. Take-off ($\mathbf{T}_{GRF}$) and landing ($\mathbf{L}_{GRF}$) ground reaction force

Vertical jump biomechanics

In a CMJ (Figure 3 and 4), the jumper starts from an upright standing position, makes a preliminary downward movement by flexing at the knees and hips, then immediately and vigorously extends the knees and hips again to jump vertically up off the ground. A CMJ is an example of a movement that benefits from the ''stretch–shorten cycle." Many human movements such as running, jumping, and throwing involve muscle actions in which the desired motion is preceded by a move-

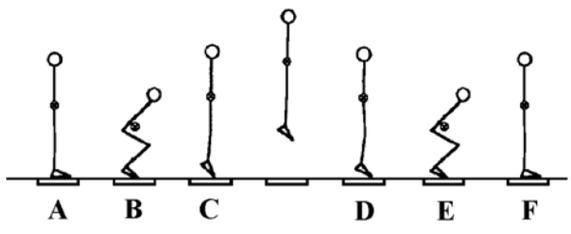

Figure 4. Counter Movement Jump Test

Methods

Subjects

The sample of subjects consisted of 21 football players from Dinamo Football Club, Zagreb (Table 2). The club is a member of the first football league of the Republic of Croatia and its manifold champion and participant in European competitions. The subjects were healthy and in a good physical condition. The investigation was carried out at the end of the preparatory period, when a high physical conditioning level was expected.

Table 2. Basic data about football players

No.	Year of birth	Weight (N)	Role in the team
1.	1974	923	Goalkeeper
2.	1982	860	Defender (back)
3.	1978	947	Defender (back)
4.	1983	715	Defender (back)
5.	1973	735	Defender (back)
6.	1979	762	Defender (back)
7.	1974	873	Defender (back)
8.	1979	830	Defender (back)
9.	1981	801	Midfield player
10.	1983	799	Midfield player
11.	1982	802	Midfield player
12.	1982	719	Midfield player
13.	1983	712	Midfield player
14.	1980	768	Midfield player
15.	1976	748	Midfiled player
16.	1983	780	Midfiled player
17.	1974	671	Midfield player
18.	1982	780	Forward (striker)
19.	1984	859	Forward (striker)
20.	1975	725	Forward (striker)
21.	1975	813	Forward (striker)
Average	20.8	791	

Force platform

A force platform (Kistler, Sweden) possesses a rectangular metal plate on top surface, measuring 400 x 600 x 100mm, with a large measuring range and a high natural frequency (1000 Hz) (Figure 5). The platform can measure and register the ground reaction forces in three components. Only the vertical component was analysed since it is dominant in performing the vertical jump test.

Statistical analysis

The Student's *t*-test was used for force variables to determine whether two independent samples were drawn from populations with different means.

Variables

Among the measured force signals, the following variables were extracted (Table 3).

Table 3. Description of all the variables used in the study

	Variables	Variable description
1.	BW	body weight [N]
2.	RTF_{MAX}	maximal take-off force with right leg [N]
3.	LTF_{MAX}	maximal take-off force with left leg [N]
4.	RTF_{MIN}	minimal take-off force with right leg [N]
5.	LTF_{MIN}	minimal take-off force with left leg [N]
6.	RLF_{MAX}	maximal landing force with right leg [N]
7.	LLF_{MAX}	maximal landing force with left leg [N]
8.	RLF_{MIN}	minimal landing force with right leg [N]
9.	LLF_{MIN}	minimal landing force with left leg [N]
10.	RT_{INDEX}	maximal take-off force with right leg divided by the examinee's body weight [N]
11.	LT_{INDEX}	maximal take-off force with left leg divided by the examinee's body weight [N]
12.	RL_{INDEX}	maximal landing force with right leg divided by the examinee's body weight [N]
13.	LL_{INDEX}	maximal landing force with left leg divided to the examinee's body weight [N]
14.	RTT_{PRI}	preparation time needed for take-off with right leg [s]
15.	LTT_{PRI}	preparation time needed for take-off with left leg [s]
16.	RLT_{DOSK}	landing time with right leg [s]
17.	LLT_{DOSK}	landing time with left leg [s]
18.	RTT_{JUMP}	take-off time with right leg [s]
19.	LTT_{JUMP}	take-off time with left leg [s]
20.	RLT_{AMOR}	shock-absorption time with right leg [s]
21.	LLT_{AMOR}	shock-absorption time with left leg [s]
22.	RTT_{UKUPN}	time needed for preparation and take-off with right leg [s]
23.	LTT_{UKUPN}	time needed for preparation and take-off with left leg [s]
24.	RLT_{UKUPN}	time needed for landing and shock-absorption with right leg [s]
25.	LLT_{UKUPN}	time needed for landing and shock-absorption with left leg [s]

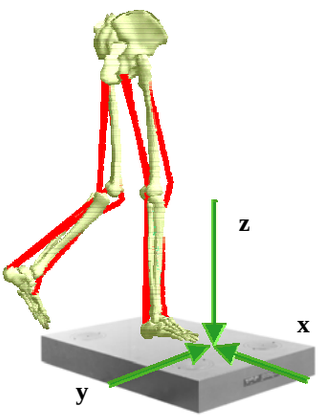

Figure 5. Force platform

Results and discussion

Based on the selected variables (Table 3), the results were calculated (Tables 4, 5 and 6).

Table 4. Student's t-test for the groups of forwards and midfield players

Grouping: POSITION
Group 1: **forward** Valid N = 5
Group 2: **midfield** Valid N = 8

	Mean forward	Mean midfield	t-value	df	p	Std.Dev. forward	Std.Dev. midfield
BW	820.00	748.25	2.14	11	0.06	75.50	46.56
RTF_{MAX}	**1779.28**	**1470.68**	**3.29**	**11**	**0.01**	**209.38**	**132.66**
$RTTF_{MAX}$	0.70	0.79	-0.77	11	0.46	0.20	0.21
RT_{INDEX}	**2.17**	**1.96**	**2.44**	**11**	**0.03**	**0.21**	**0.10**
RLF_{MAX}	3313.38	3319.03	-0.02	11	0.99	684.24	409.49
RL_{INDEX}	4.09	4.42	-0.85	11	0.41	1.05	0.32
LTF_{MAX}	1639.82	1505.19	1.82	11	0.10	126.90	131.13
LT_{INDEX}	2.00	2.01	-0.11	11	0.91	0.10	0.12

Table 5. Student's t-test for the groups of defenders and forwards

Grouping: POSITION
Group 1: **defence** Valid N = 8
Group 2: **forward** Valid N = 5

	Mean defender	Mean forward	t-value	df	p	Std.Dev. defender	Std.Dev. forward
BW	811.63	820.00	-0.20	11	0.85	73.00	75.50
RTF_{MAX}	1700.47	1779.28	-0.57	11	0.58	260.94	209.38
RT_{INDEX}	2.09	2.17	-0.89	11	0.39	0.15	0.21
RLF_{MAX}	3376.04	3313.38	0.15	11	0.89	789.22	684.24
RL_{INDEX}	4.16	4.09	0.13	11	0.90	0.89	1.05
LTF_{MAX}	1601.30	1639.82	-0.40	11	0.69	186.51	126.90
LT_{INDEX}	1.97	2.00	-0.51	11	0.62	0.12	0.10

Table 6. Student's t-test for the groups of midfield players and defenders

Grouping: POSITION
Group 1: **midfield** Valid N = 8
Group 2: **defence** Valid N = 8

	Mean midfield	Mean defender	t-value	df	p	Std.Dev. midfield	Std.Dev. defender
BW	748.25	811.63	-2.07	14	0.06	46.56	73.00
RTF_{MAX}	**1470.68**	**1700.47**	**-2.22**	**14**	**0.04**	**132.66**	**260.94**
LTF_{MAX}	1505.19	1601.30	-1.19	14	0.25	131.13	186.51
RTT_{PRI}	0.37	0.33	0.89	14	0.39	0.10	0.07
RTT_{JUMP}	0.47	0.47	0.14	14	0.89	0.08	0.09
RTT_{UKUPN}	0.84	0.79	0.64	14	0.53	0.15	0.12
RT_{INDEX}	1.96	2.09	-1.96	14	0.07	0.10	0.15
RLF_{MAX}	3319.03	3376.04	-0.18	14	0.86	409.49	789.22
RLT_{UKUPN}	0.52	0.63	-1.88	14	0.08	0.10	0.14
LTT_{UKUPN}	0.80	0.77	0.39	14	0.70	0.15	0.10

Comparing the results of strikers and midfield players (Table 4) yielded by the Student's *t*-test, the two groups proved to differ significantly ($p<0.05$) in two out of 25 variables: RTFmax *(maximum take-off force with right leg)* and RT index *(relative take-off force with right leg, ratio of maximum take-off force with right leg* and *body mass RTFmax/BW)*. Other variables that differ, although not statistically significantly, include *BW* ([p=0.06], *body mass)* and *LTFmax* ([p=0.10], *maximum take-off force with left leg)*. In order for a team to be successful, these two groups of players have to play different roles in the game. The primary role of midfielders is to organise the game and pass the ball from the defence to the attack phase. This transition determines whether the strikers will get a chance to win the ball and build a high-quality offence. This role determines the main characteristic of midfield players: they move within a wide radius and consequently boast of a high functional-aerobic preparedness. Unlike midfielders, the strikers move within a much narrower radius and are more focused on the opponent's goal. Their game is dominated by explosive power in one-on-one situations, headers and shots at the goal, which may be a logical explanation for the differences observed between these two groups. Comparing the results of the defenders and strikers (Table 5), obtained in the Student's *t*-test, it is obvious that the two groups of examinees show no major difference ($p<0.05$) in any of the total number of 25 variables. The main characteristics of the defenders and strikers involve explosive power in one-on-one and head kicks. Power of the kick is also very important for defenders because it allows them to remove the threat to their goal. Precision of the kick is not as critically important as it is in strikers. All this can be taken as a logical explanation for the lack of differences between the two tested groups. Comparing the results of the midfielders and defenders (Table 6) yielded by the Student's *t*-test, out of the total number of 25 variables the two groups showed a significant difference ($p<0.05$) in variable *RTFmax* ([p=0.04], *maximum take-off force with right leg)*. Other variables in which there was a statistically minor difference (that could possibly turn into a major difference in the case of a larger number of examinees) include *BW* ([p=0.06], *body mass)* and *RTindex* ([p=0.07], *relative take-off force with right leg, ratio of maximum take-off force with right leg* and *body mass Fmax/BW)*. Based on the des-cribed differences between the groups (midfielders – strikers and defenders – strikers) one can con-clude that the differences between the midfield and defenders groups were also to be expected given their characteristic roles and the functional-motor characteristic of the individual players.

Conclusion

This study aims to provide an analytical insight into the bio-mechanical interaction between the body and the ground and thus, indirectly, into the complexity and functioning of the athlete's neuromuscular system during a simple vertical jump test. Statistically processed results of a football club have yielded statistically significant variations, which means that the test could be applied to a larger number of examinees with greater precision and reliabily. The test can be carried out at any point during the training process as an additional indication of preparedness benefiting both the coach and the sportsmen themselves. The research produced the expected results.

Acknowledgment
This study was supported by the Ministry of Science and Technology of the Republic Croatia (Project No. 0034-206, "Creating centre of excellence for locomotion study").

References

Kaneko, M., Fuchimoto, T., Toji, H. & Suei, K.(1983). Training effects of different loads on the force velocity relationship and mechanical power output in human muscle*, Scandinavian Journal of Sports Science*, *5*(2), 50-55.

Kasović, M., Medved, V. (1998). Some EMG and takeoff features to characterise alpine skiers. In R. Madjarević, (Ed.), *IMEKO Proceedings, 8th International IMEKO TC-13 Conference on Measurement in Clinical Medicine* ((3), (pp.148-151), Dubrovnik, Croatia.

Linthorne N.P. (2001). Analysis of standing vertical jumps using a force platform, *American Journal of Physics, 69*(11), 1198-1204.

Luhtanen, P. (1994). Biomechanical aspects. In B. Ekblom (Ed*.), Football (Soccer) Handbook of Sports Medicine and Science*, London: Blackwell Scientific Publications.

Maneval, M.W., & Poole, W.H. (1987). The effects of two ten week depth jumping routines on vertical jump performance as it relates to leg power. *International Journal of Swimming Research, 3*(1), 11-14.

Row, B. & Hreljac, A. (2000). The one-legged and two-legged vertical jumps: a kinetic and temporal analysis. *24th Annual Meeting of the American Society of Biomechanics, www.asb-biomech.org.*

Sale, D.G. (1988). Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise*, *20*(5), 135-143.

Wilson, G.J., Newton, R.U., Murphy, A.J., & Humphries, B.J. (1993). The optimal training load for the development of dynamic athletic performance*, Medicine and Science in Sports and Exercise*, *25*(11), 1279-1286.

Withers, R.T., Maričić, Z., Wasilewski, S. & Kelly, L. (1982) Match analysis of Australian soccer players. *Journal of Human Movement Studies*, *8*, 159-176.

Young, W. (1995). Specificity of jumping ability. *Sports Coach*, 22-25.

Received: November 2, 2002
Accepted: December 18, 2002

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KARAKTERISTIKE ODRAZA I DOSKOKA VRHUNSKIH NOGOMETAŠA: ANALIZA REAKCIJSKE SILE PODLOGE

Sažetak

Uvod

Za bolje razumijevanje aktivnosti vezanih uz nogomet prisjetimo se nekih općenitih značajki igre. Napadi koji rezultiraju postizanjem pogotka traju kraće od 25 sekundi, a u njima sudjeluju dva to šest igrača koji izmijene između jednoga i šest dodavanja loptom. Za postizanje pogotka prosječno je potrebno 16-30 napada i 7-10 udaraca u okvir vrata. Udaljenost koju prijeđe igrač za vrijeme utakmice ovisi o njegovoj poziciju i ulozi u igri (Luhtanen, 1994). Igrači u prosjeku naprave 96 sprintova, duljine kojih variraju između 1.5m i 105m. Nogometna igra obiluje promjenama smjerova, skokovima i duelima jedan-na-jedan (Withers i sur., 1982). Oko 350 dodavanja odigra se na prvi, 150 na drugi, a ostatak se odigra nakon višestrukih dodira s loptom, tj. nakon driblinga. Biomehanička analiza može poslužiti za karakterizaciju i ocjenu uspješnosti nogometne igre. Cilj je ovoga rada doprinijeti boljem razumijevanju neuromišićne aktivnosti pokreta tijekom igranja nogometa, što bi u konačnici pridonijelo poboljšanju treninga nogometaša. Jedan od najvažnijih čimbenika u strukturi gibanja je eksplozivna snaga donjih ekstremiteta. Manifestira se u nizu struktura kretanja nogometaša, kao što su dribling, presretanje igrača s loptom, promjena smjera i u mnogima drugima… Konkretna uloga igrača na terenu, međutim, pobliže definira okolnosti vezane za eksplozivnu snagu. Od vratara se očekuje što bolja reakcija na upućenu loptu prema golu, što efikasnije pokrivanje terena ispred gola, a u slučaju krive inicijalne procjene smjera lopte, što brži povratak na najbolju vratarsku poziciju itd. Obrambeni igrači bi trebali imati dobro razvijene vještine brzog mijenjanja smjera kretanja u igri jedan-na-jedan, odnosno moraju biti sposobni osvojiti loptu ili barem spriječiti promjenu posjeda lopte. Igrači sredine terena bi se trebali brzo kretati iz napada u obranu i obrnuto, spriječiti prolaz lopti do svoga gola i izvesti duga dodavanja do svojih napadača. Napadači bi trebali biti sposobni u igri jedan-na-jedan driblingom nadigrati protivničke obrambene igrače, uputiti što jači i precizniji udarac na gol itd.

Eksplozivna snaga je definirana kao sposobnost generiranja maksimalne sile koju određeni mišići/grupa mišića može proizvesti u jedinici vremena. U slučaju donjih ekstremiteta, dominantnu ulogu u proizvodnji sile imaju ekstenzor potkoljenice (m. *quadriceps*), fleksor potkoljenice (m. *biceps femoris*) i ekstenzor stopala (m. *soleus*). Do sada su biomehanička istraživanja bila usredotočena na nogometne udarce, dok se ostale aktivnosti (skokovi, promjene smjera kretanja, zaustavljanje, kretanje …) nisu detaljno proučavale. Prijašnja istraživanja pokazala su da postoji stanovita veza između vertikalnoga skoka i eksplozivne snage donjih ekstremiteta (Kasović i Medved, 1998). Nekoliko čimbenika utječe na eksplozivnu snagu kod vertikalnog skoka. Komi (prema Koneko et al, 1983) smatra da mišićna struktura ima odlučujuću ulogu za manfestaciju eksplozivnu snage. Sportaši s većim postotkom 'bijelih' (brzokontraktilnih) mišićnih vlakana eksplozivniji su od sportaša s većim postotkom 'crvenih' (sporokontraktilnih) mišićnih vlakana. U sklopu ovoga rada procijenjena je eksplozivna snaga donjih ekstremiteta na temelju mjerenja vertikalne sile reakcije podloge pomoću platforme za mjerenje sila kod vertikalnog skoka. Analizom dobivenih vrijednosti pokušala su se objasniti razlike između igrača na različitim igračkim pozicijama.

Materijal i metode

Uzorak ispitanika činio je 21 igrač nogometnoga kluba 'Dinamo', Zagreb, koji je jedan od ponajboljih klubova u R Hrvatskoj. Ispitanici su bili zdravi i u dobroj fizičkoj kondiciji, te u završnoj fazi priprema kada se očekuje visok stupanj forme. Mjerenje sila reakcije podloge provedeno je platformom za mjerenje reakcijske sile podloge (Kistler, Švicarska), dimenzija 400 ´ 600 ´ 100 mm s frekvencijom uzorkovanja od 1000 Hz. Uređaj mjeri vrijednosti u sve tri koordinatne osi, dok je u radu analizirana samo vertikalna komponenta koja je dominantna u vertikalnom skoku. U sklopu statističke analize korišten je studentov *t*-test za nezavisne uzorke.

Rezultati i diskusija

Rezultati napadača i igrača sredine terena se prema *t*-testu statistički značajno razlikuju ($p<0.05$) za vrijednosti maksimalnog iznosa sila desne noge, odnosno za vrijednosti maksimalnog iznosa sila desne noge podijeljenih s masom ispitanika (od ukupno 25 različito definiranih varijabli/vrijednosti). Glavna uloga igrača sredine terena je organizacija igre, tj. prihvat i prijenos lopte od obrane za igrače u napadu. Zbog toga se igrači sredine terena relativno puno kreću. Za razliku od njih napadači se puno manje kreću, ali njihovu igru karakterizira igra jedan-na-jedan, koja postavlja dodatne zahtjeve na eksplozivnost, igru gla-

vom i preciznost udarca na gol. Stoga i ne čudi proizašao rezultata da su napadači eksplozivniji od igrača sredine terena. Usporedba obrambenih igrača i napadača pokazuje da među njima nema značajne razlike ($p<0.05$) za bilo koju od 25 različitih varijabli. To je očekivan rezultat budući da i jedni i drugi trebaju biti dovoljno eksplozivni u igri jedan-na-jedan te u izvedbi udaraca po lopti u dodavanjima ili udarcima na gol. Usporedba obrambenih igrača i igrača sredine terena daje analogne rezultate kao i za analizu napadača i igrače sredine terena, tj. *t*-test pokazuje da su rezultati statistički značajni za vrijednosti maksimalnog iznosa sila desne noge.

Zaključak

Ovaj rad je analitičkim putem prikazao da postoji biomehanička interakcija između tijela i sila reakcije podloge te tako na indirektan način ukazao na funkcioniranje živčanomišićnog sustava nogometaša prilikom vertikalnog skoka. Time se može opravdati primjena prikazanog testa za utvrđivanje eksplozivne snage nogometaša. Dobivene su razlike u pokazateljima maksimalne sile reakcije podloge između igrača sredine terena i napadača, što je objašnjeno specifičnošću izvedbi različitih struktura gibanja na različitim pozicijama u igri.