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15–16 year old female basketball, volleyball and soccer players' vertical movement characteristics

Prof. Dr. Darius Radžiukynas, Assoc. Prof. Dr. Nelė Žilinskienė, Assoc. Prof. Dr. Eglė Kemerytė-Riaubienė, Assoc. Prof. Dr. Raminta Sakalauskaitė
Lithuanian University of Educational Sciences

Summary

It is important to be aware what kind of the motor skills are developed by practicing different sports, and to learn whether exist general indices, settling sport movement performance level. So far, a little number of researches dealt with the question about the main kinematic and kinetic indices which have influence on effectiveness of athletes' movement in various directions, by this ensuring space and time advantage, as well as with the questions on body movement momentum and absolute speed, acceleration and force, motion precision; these parameters make the main effect on sport results. The answers to these questions might be of assistance in more objective evaluation of athletes' abilities, correction of training process, as well as in the prognosis of sport results. The aim of the work was to establish and compare 15–16 year old female basketball, volleyball and soccer players' vertical movement anthropometric indices and skills. 15–16 year old female players of basketball (n = 13), volleyball (n = 9) and soccer (n = 11) participated in the research.

Anthropometric indices – height (m), body weight (kg), BMI (r/u), fat (%) and muscle (%) mass were measured. Applying the method of tenzodynamometry, players' kinematic and kinetic characteristics when performing standing two feet vertical jump with arm movement were established. The following indices were recorded: squat duration d_s (s), take-off duration d_t (s), flight phase duration d_f (s), total jump duration d_j (s), squat speed V_s (m/s), body movement speed V (m/s), squat depth s_d (m), jump height h (m), greatest take-off force F_{max} (N), force increase maximum speed F_v (N/s), muscle reactivity R (Hz), work A (J), power P (W) and relative power P_r (W/kg).

Mathematical statistics. Arithmetic mean ($\bar{x}$), standard deviation (±S), significance level ($p < 0.05$) and data correlation (r) were calculated. The data were processed using SPSS program (version 13.0).

The results showed significant differences in basketball, volleyball and soccer players' anthropometric, kinematic and kinetic indices. The basketball players' height and body mass indices were of the highest value. Quantitative indices of BMI, muscle and fat mass were of similar value for all the players and corresponded to the standards of female athletes of such period of age. The highest jump value h (m) was recorded for volleyball players (0.40 m), less – for basketball players (0.37), and it was significantly less ($p < 0.005$) for soccer players (0.33) comparing to volleyball players. Take-off force F_{max} (N) was significantly greater for basketball players in comparison with volleyball and soccer players ($p < 0.001$). Leg muscle reactivity R (Hz) appeared to be the best for the soccer players, and was considerably different from that of the volleyball players ($p < 0.002$). Indicators of the work performed A (J), power P (W) and relative power P_r (W/kg) were the highest for basketball players, they differed significantly from those of soccer players ($p < 0.001$).

Correlation analysis of vertical movement kinematic, kinetic and anthropometric indices proved the main characteristics for the most objective evaluation of the players' motor skills being BMI, take-off duration, flight phase duration and jump height, absolute force and relative power, body movement speed, speed of force increase and reactivity.

Keywords: *female players of basketball, soccer and volleyball, anthropometric, kinematic and kinetic indices, vertical jump, correlation.*

Introduction

The main practical form of sport expression is athletes' movement, which includes biological and mechanical movements. It is determined by specificity of certain sports, as well as by sport competences developing technologies. Complex sport movement is a characteristic feature for basketball, volleyball and soccer sports. A common movement feature for the athletes practicing these sports is that they move in various directions interacting with support, with or without a ball, simultaneously performing both individual and team actions. There is a wide variety of movement directions: running forward and back, side forward and side back, side running, jump up, up forward, side up, up back, jump side back. These movements happen performing take-off by both legs or changing left and right leg. All the movements in the named directions are performed by different body position, support reaction force

and body movement speed. Diversity and duration of the movement is conditioned by game activity situations, players' functions and tactic of the game. The common feature in these games is also the fact that take-off by both legs, jump height and anthropometric indices moving in vertical direction very often have an essential influence on the game outcomes. In basketball, this occurs in throwing the ball and fighting for the ball, in volleyball – hitting or blocking the ball, while in soccer it manifests in heading up and fighting for the ball in the air (Karapidis et al., 2001; Butautas, 2002; Palao et al., 2008; Riggs et.al., 2009; Buško, 2009; Zuoza et al., 2011; Claramunt et al., 2011; Vasill et al., 2012; Soundara, Pushparajan, 2012; Radžiukynas, 2013).

These games are a complex and integral form of motor skills, special creative thinking, self-analysis and self-expression. Its effectiveness is proved by effective individual and team movements.

The main aim of the movement is to acquire space and time advantage against the opponents, as well as to perform precise movements and actions. This space and time advantage is acquired by the athlete's movement in various directions only when greater body movement momentum and absolute speed, acceleration and capacity in needed direction is achieved with regard to the opponent, performing precise movements (Giatsis et al., 2007; Tilp et al., 2008; Radžiukynas, 2013; Gražulis, 2013).

Nevertheless, quantitative and qualitative characteristics of these actions might be different due to difference of specificity, duration and tactics of these games. These specific characteristics are likely to be shown by vertical jump kinematic and kinetic indices and, both theoretically and practically, it can be used for more successful athletes' selection, planning of training sessions, understanding specificity of vertical movement that is conditioned by age, gender and sports.

Considering the named, it is urgent to disclose anthropometric indices, as well as kinetic and kinematic indices in relation with the support. It is also important to reveal their general and specific features that are formed under specific training and competitions conditions for each game.

The aim of the research was to disclose and compare vertical movement anthropometric indices and skills of 15 to 16 year old female basketball, soccer and volleyball players.

The methods of the research:

1. Anthropometry: Age (y). Height (m). Body mass (kg). BMI (r/u). Body fat mass (%). Muscle mass (%). The indices recorded using the scales of SOEHLE PROFESSIONAL Fitness Scale.

2. Tenzodynamometry. Players' motor skills were established by performing dynamic jump up with arm movement. This kind of jump was chosen regarding that kinematic and kinetic indices during its performance are in correlation with the indices of movement in various directions, as well as with game activity (Radžiukynas, 2013). Jumps were performed on tenzoplatform, and the special program was used for recording and calculating kinematic and kinetic indices (Danisevicius, Gonestas, 2001; Muckus, 2006).

The following indices were recorded and calculated:

1. Squat duration d_s (s),
2. Take-off duration, d_t (s),
3. Flight phase duration d_f (s),
4. Total jump duration d_j (s),
5. Squat speed V_s (m/s),
6. Body movement speed V (m/s),
7. Squat depth s_d (m),
8. Jump height h (m),
9. Greatest take-off force F_{max} (N),
10. Greatest force increase speed F_v (N/s),
11. Muscle reactivity R (Hz),
12. Work A (J),
13. Power (P),
14. Relative power P_s (W/kg).

3. Mathematical statistics.

Arithmetic mean ($\bar{x}$) and standard deviation (±S) were calculated. To establish the means difference reliability between the groups, Student t criterion for dependent and independent samples was applied. Significance levels – $p < 0.05–0.001$. Correlation was established using Pearson method of correlation. Interpretation of correlation coefficient (r) was performed regarding the volume of samples. SPSS program (13.0 version) was employed for calculation of the results.

The research was performed in Sport physiology and biomechanics laboratory of Lithuanian University of Educational Sciences. The research included female players (aged 15–16) of three teams: basketball players (n = 13) ("Young talents" team), volleyball players (n = 9), and soccer players (n = 11) ("Žalgiris" team).

Results of the research

The research data showed that basketball players, aged 15–16, are taller comparing to volleyball and soccer players of the same age (p = 0.010, p = 0.017). Body mass of basketball players is significantly bigger than soccer players' mass (p = 0.012). BMI is within the norm limits of the athletes in all teams, however, significant difference was established between soccer and volleyball players' indices (p = 0.021) (Table 1).

Table 1

Players' anthropometric indices

Indices	Soccer players x ± S	Basketball players x ± S	Volleyball players x ± S
1. Age (y)	15.72 ± 3.13	16.38 ± 0.76	15.77 ± 0.66
2. Height (m)	1.70 ± 0.07*	1.80 ± 0.09*	1.71± 0.04*
3. Body mass (kg)	59.89 ± 10.18*	71.17 ± 9.91*	67.33 ± 6.53
4. BMI	20.00 ± 2.31*	21.47 ± 2.17	22.02 ± 1.30*
5. Body fat (%)	20.80 ± 3.54	20.35 ± 2.94	21.07 ± 2.09
6. Muscle mass (%)	41.33 ± 3.03	40.99 ± 2.35	41.20 ± 2.52

Note. * p < 0.05. ** p < 0.01.

Recommended body fat norm is 14–20% for female athletes, while our investigated players exceeded this limit by 0.5–1%. Players' percentage muscle mass is sufficient, as it should make not less than 40%. Players' selection according to their anthropometric indices can be considered as good. Comparing to similar researches, volleyball players' height indices should be greater (Zuoza et al., 2011).

Soccer, basketball and volleyball players' vertical dynamic jump kinematic and kinetic indices differ (Table 2). The best squat result (d_s) was demonstrated by basketball players, comparing to soccer (p = 0.002) and volleyball (p = 0.008) players. The results of take-off duration (d_t) are significantly better for soccer players comparing to volleyball players (p = 0.032). Volleyball players demonstrated the best result in total jump duration (d_j), which included squat, take-off and flight phases. It differed significantly from soccer (p = 0.001) and basketball (p = 0.012) players' results (Table 2).

Squat speed V_s (m/s) was the greatest for volleyball players, however, it did not differ significantly from the results achieved by soccer and basketball players. The biggest body movement speed V (m/s) was obtained by basketball players, and it was significantly (p = 0.001) bigger than soccer players' result. Squat s_d (m) of volleyball players was significantly deeper than that of basketball players (p = 0.028). Volleyball players demonstrated the highest jump result h (m), and their jump height was of significant difference from the soccer players' result (p = 0.002) (Table 2).

Table 2

Kinematic and kinetic indices of soccer, basketball and volleyball players' movement in vertical direction

Indices	Soccer players (n = 11) x ± S	Basketball players (n = 13) x ± S	Volleyball players (n = 9) x ± S
1. Squat duration d_s (s)	0.44 ± 0.09*	0.31 ± 0.07*	0.41 ± 0.07*
2. Take-off duration d_t (s)	0.21 ± 0.03*	0.22 ± 0.04*	0.26 ± 0.01*
3. Flight phase duration d_f (s)	0.52 ± 0.03	0.54 ± 0.02	0.57 ± 0.02
4. Total jump duration d_j (s)	0.93 ± 0.12*	1.10 ± 0.11*	1.24 ± 0.12*
5. Squat speed V_s (m/s)	0.95 ± 0.12	0.93 ± 0.20	1.16 ± 0.34
6. Body movement speed V (m/s)	2.40 ± 0.13*	2.88± 0.21*	2.84 ± 0.25*
7. Squat depth s_d (m)	–0.22 ± 0.05	–0.18 ± 0.06*	–0.25 ± 0.09*
8. Jump height h (m)	0.33 ± 0.04*	0.37 ± 0.03*	0.40 ± 0.03*
9. Greatest take-off force F_{max} (N)	1425.79 ± 251.27*	1883.86 ± 279.45*	1630.41 ± 114.11*
10. Greatest force increase speed F_v (N/s)	10309.181 ± 2086.19*	9286.54 ± 2700.51*	7392.84 ± 2009.26*
11. Muscle reactivity R (Hz)	18.01 ± 4.90*	13.71 ± 4.64	11.25 ± 2.99*
12. Work A (J)	351.96 ± 70.55	559.66 ± 130.17*	550.65 ± 105.04*
13. Power P (W)	1586.28 ± 269.85*	2469.08 ± 374.39*	2098.87 ± 237.26*
14. Relative power P_r (W/kg)	26.59 ± 3.10*	34.91 ± 4.49*	31.48 ± 5.06*

Note. * p < 0.05. ** p < 0.01.

Basketball players demonstrated the greatest take-off force Fmax (N). It was significantly greater comparing to volleyball (p = 0.019) and soccer (p = 0.001) players' results. The greatest force increase speed F_v (N/s) was recorded in soccer players' results, being significantly greater in comparison with volleyball players' data (p = 0.005). Soccer players demonstrated the best results of muscle reactivity R (Hz), which significantly differed from volleyball players' results (p = 0.002).

The indices of the work A (J), performed by basketball players, were significantly greater than those of soccer players (p = 0.001). Indices of power P (W) and relative power P_r (W/kg) were the best for the basketball players and were significantly different from the ones of soccer players (p = 0.001) (Table 2).

Players' body mass index was in strong correlation with the results of volleyball players' take-off duration (r = 0.792), work (r = 0.671) and relative power (r = –0.642) indices, as well as with the indices of soccer players' greatest force (r = 0.628) and of basketball players' muscle reactivity (r = 0.652) (Table 3).

Table 3

Correlation of BMI with the indices of body movement in vertical direction

Indices	Soccer players r	Basketball players R	Volleyball players r
1. Take-off duration d_t (s)	0.272	0.466	0.792*
2. Greatest take-off force F_{max} (N)	0.628*	0.063	–0.081
3. Muscle reactivity R (Hz)	–0.382	–0.652*	–0.092
4. Work A (J)	0.629*	0.561	0.671*
5. Relative power P_r (W/kg)	–0.396	–0.408	–0.642*

Note. * p < 0.05. ** p < 0.01.

Strong body movement speed indices correlation with relative power indices of soccer (r = 0.690) and volleyball (r = 0.724) players was established, which was weaker with basketball players' (r = 0.401) indices. Data showed that volleyball players' movement in vertical direction was negatively influenced by fat mass (r = –0.697), while muscle mass (r = 0.687) and absolute power (r = 0.792) had a positive effect. Body movement speed indices for basketball players were in strong correlation with their squat speed (r = 0.640) and work (r = 0.686) results, however, for soccer players correlation was observed with flight phase duration (r = 0.665) indices (Table 4).

Table 4

Correlation of body movement speed V (m/sec.) indices

Indices	Soccer players, r	Basketball players, r	Volleyball players, r
1. Body fat mass	–0.332	0.044	–0.697*
2. Body muscles mass	0.384	–0.102	0.687*
3. Flight phase duration d_f (s)	0.665*	0.314	0.558
4. Squat speed V_s (m/s)	–0.168	0.640*	0.193
5. Work A (J)	0.249	0.686**	0.603
6. Power P (W)	0.274	0.408	0.792*
7. Relative power P_r (W/kg)	0.690*	0.401	0.724*

Note. * p < 0.05. ** p < 0.01.

Flight phase duration of all players was in strong correlation with the total jump duration. For basketball and volleyball players, it had correlation with squat duration and work, while for soccer and basketball players – with relative power. Take-off duration for volleyball players was in strong correlation with BMI (Table 5).

Table 5

Correlation between take-off duration (d_j) and body movement in vertical direction indices

Indices	Soccer players r	Basketball players R	Volleyball players r
1. BMI	0.272	0.466	0.792*
1. Squat duration d_s (s)	0.460	0.658*	0.863**
2. Total jump duration d_j (s)	0.634*	0.783**	0.894**
3. Work A (J)	0.580	0.749**	0.802**
4. Relative power P_r (W/kg)	–0.658*	–0.595*	–0.582

Note. * p < 0.05. ** p < 0.01.

Relative power appears to be an important index for female soccer, basketball and volleyball players aged 15 to 16. It is in strong correlation with soccer players' take-off duration and body movement speed, and with take-off duration and squat depth for basketball players. Volleyball players' index of relative power is in strong correlation with BMI, body fat mass, body muscle mass, body movement speed and power (Table 6).

Table 6

Correlation of relative power indices

Indices	Soccer players, r	Basketball players, R	Volleyball players, r
1. BMI	–0.396	–0.408	**–0.642***
2. Body fat mass	–0.593	–0.213	**–0.857****
3. Body muscle mass	0.596	0.172	0.715*
4. Take-off duration d_t (s)	**–0.658***	**–0.595***	–0.582
5. Body movement speed V (m/s)	–0.690*	0.401	0.724*
6. Squat depth s_d (m)	0.235	0.615*	0.047
7. Power P (W)	0.414	0.512	0.783*

Note. * p < 0.05. ** p < 0.01.

Discussion

The obtained research results confirm our hypothesis. Female players aged 15 to 16 of different sport games differ according to certain anthropometric, kinematic and kinetic indices of moving in vertical direction; these indices demonstrate peculiarities of sport skills in the athletes playing these sports.

Purposeful training loads have influence on proportional body composition. Regarding this fact, established optimal muscle and fat mass ratio is important in biological and sport aspects.

Considering the research results, several recommendations on further development of young athletes' movement skills can be provided, e.g., basketball players should try to reach legs muscle reactivity similar or equal to that of soccer players. This is especially important for improvement of momentum movement speed, necessary for basketball players when performing quick and deceptive movements in various directions, or performing movement into various directions, both with or without a ball. Meanwhile, soccer players should perfect and reach for the results of jump height similar to volleyball players, as this index is important in soccer players' fighting for the ball or shooting.

Soccer players' results of relative power considerably fall behind the results of basketball and volleyball players. This might have negative influence in body position control during the game changing speed of movement in various directions.

Scientific researches in this field explicit existing motor skills of the players aged 15–16 and disclose possibility to investigate factors of influence on effectiveness of game activity.

It was established that locomotion movement in various directions of various age, gender and sport mastership level players can be evaluated according to the following indices: take-off from support force and duration, resulting in individual for each athlete optimal squat duration, depth, speed, body movement speed, take-off and flight phase duration, absolute and relative power and muscle reactivity. Integral expression and change of all these indices ensure athletes' successful movement in space and time. Basing on the results of the research, young athletes' training systems, programs, impact and change of training loads, training recovery time and its educational trends can be modified and improved (Kaškevičius, 2015).

Young basketball players' motor skills depend on their age and training methodic (Butautas, 2002; Radžiukynas, Šatas, Kildišius, 2004), while for the adult athletes, more influence is made by individual skills of movement in various directions, ensuring space and time advantage in various gaming activity situations (Karapidis et al., 2001; Maksvytis et al., 2001; Čižauskas, 2003; Radžiukynas et al., 2007, 2010, 2012; Claramunt et al., 2011).

Volleyball players' motor skills depend on indices of force and spring features (Busko, 2009), as well as on velocity and explosive power (Vasill et al., 2012), vertical jump height indices – on force and power indices (Riggs et al., 2009), which results in body movement effectiveness (Giatsis et al., 2007). Due to these facts, volleyball players' training sessions include speed (Ivinski, 2001), force (Carrera, Reyers, 2013) development, as well as various vertical jumps (Soundera, Pushparajan, 2012). Also, established was the level of young volleyball players' body mass index and respiratory functions, as well as influence of these indices on players' motor skills (Zuoza et al., 2011). Scientific literature also presents the results of integral expression of elite female beach volleyball players' (aged 17–18) skills and functional capacity (Pileckaitė, 2013), as well as the influence of this integration on game effectiveness (Palao et al., 2008).

The researches establish personal and sport competencies expression in young Lithuanian soccer players' development (Gražulis, 2013; Radžiukynas et al., 2015) and didactic trends of adult athletes' training process (Bangsbo, 1994; Radžiukynas, Jančiauskas, 2003; Kazakevičius et al., 2006).

Our research results complement recognition of athletes' motor skills and can be used in female athletes (aged 15–16) training. Training sessions and competitions of three sports under investigation serve for development of athletes' good motor skills. Athletes of these sports are able to quickly change body position and perform a quick take-off from support, to reach optimal body movement speed and to control body motions. Correlation between the indices shows changes of the athletes' biological maturity and anthropometric indices, as well as peculiarities of training purposefulness and body functional systems' adaptation to training loads. It is an effective trend of understanding, helping to improve young basketball, soccer and volleyball players' development.

Conclusions

1. Body mass, muscle and fat mass indices of all the players correspond to model characteristics of the athletes of this age; however, differentiating features of anthropometric indices exist. Basketball players are the highest and their body mass is the greatest, while body mass index is the greatest for volleyball players.

2. Vertical body movement kinematic and kinetic indices when performing both legs jumping possess general and individual characteristics. No significant differences were established for the flight phase duration and squat speed indices between the soccer, basketball and volleyball players' groups. The other indices were of significant difference: the greatest take-off results were achieved by soccer players, basketball players demonstrated the best results in squat speed, body movement speed and power, and volleyball players showed the deepest squat, highest jump and longest total jump time results.

3. Vertical movement kinematic, kinetic and anthropometric indices correlation showed existing relation of different strength, conditioned by sport motion peculiarities of different game sports.

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15–16 METŲ KREPŠININKIŲ, TINKLININKIŲ, FUTBOLININKIŲ JUDĖJIMO VERTIKALIA KRYPTIMI YPATUMAI

Prof. dr. Darius Radžiukynas, doc. dr. Nelė Žilinskienė, doc. dr. Eglė Kemerytė-Riaubienė, doc. dr. Raminta Sakalauskaitė
Lietuvos edukologijos universitetas

SANTRAUKA

Sportinio judėjimo gebėjimus ugdo skirtingos sporto šakos ir bendri sportinį rezultatyvumą lemiantys sportinio judėjimo rodikliai. Iki šiol mažai tirta, kokie pagrindiniai kinematiniai ir kinetiniai rodikliai turi įtakos sportininkų judėjimo įvairiomis kryptimis efektyvumui ir užtikrina erdvės ir laiko pranašumą, kaip kinta kūno judėjimo momentinis, absoliutusis greitis, pagreitis ir galingumas, judesių tikslumas, kurie iš esmės nulemia sportinius rezultatus. Tai gali padėti objektyviau įvertinti sportininkų gebėjimus, koreguoti treniruočių procesą ir prognozuoti rezultatus.

Tyrimo tikslas – nustatyti ir palyginti 15–16 m. merginų krepšinio, futbolo, tinklinio žaidėjų antropometrinius rodiklius ir judėjimo vertikalia kryptimi gebėjimus.

Tyrime dalyvavo 15–16 m. merginos krepšininkės (n = 13), tinklininkės (n = 9), futbolininkės (n = 11).

Antropometriniu metodu nustatyti: ūgis (m), kūno masė (kg), KMI, kūno riebalų kiekis (%), raumenų masė (%). Tenzodinamometrijos metodu nustatyti žaidėjų kinematiniai ir kinetiniai rodikliai atlikus dinaminį šuolį aukštyn atsispyrus abiem kojomis su rankų mostu. Registruoti rodikliai: pritūpimo trukmė tp (s), atsispyrimo trukmė ta (s), polėkio trukmė ts (s), viso šuolio trukmė tš (s), pritūpimo greitis Vp (m/s), kūno masės centro judėjimo greitis V (m/s), pritūpimo gylis pg (m), šuolio aukštis h (m), didžiausia jėga F_{max} (N), jėgos augimo didžiausias greitis F_{max} (N/s), reaktyvumas R (Hz), darbas A (J), galingumas P (W), santykinis galingumas Ps (W/kg).

Matematinė statistika. Apskaičiuoti rodiklių aritmetiniai vidurkiai ($\bar{x}$), standartiniai nuokrypiai (±S), rodiklių skirtumų reikšmingumo lygmuo ($p < 0,05$), koreliacija tarp rodiklių (r). Skaičiavimas atliktas SPSS programa (13,0 versija).

Tyrimų rezultatai parodė, kad egzistuoja reikšmingi krepšininkių, tinklininkių, futbolininkių antropometrinių ir kinematinių bei kinetinių rodiklių skirtumai. Krepšininkės yra aukščiausios ir jų kūno masė didžiausia. KMI, raumenų, riebalų kiekybiniai rodikliai visų žaidėjų yra panašūs ir atitinkantys šio amžiaus sportininkių standartus. Aukščiausiai pašoka h (m) tinklininkės (0,40 m), šiek tiek mažiau krepšininkės (0,37 m) ir reikšmingai mažiau ($p < 0,005$) futbolininkės (0,33 m), palyginti su tinklininkėmis. Reikšmingai didesnė atsispyrimo jėga F_{max} (N) yra krepšininkių, palyginti su tinklininkėmis ir futbolininkėmis ($p < 0,001$). Kojų raumenų reaktyvumas R (Hz) geriausias yra futbolininkių ir skiriasi nuo tinklininkių ($p < 0,002$). Atlikto darbo A (J), galingumo P (W) ir santykinio galingumo Ps (W/kg) rodikliai geriausi yra krepšininkių ir reikšmingai skiriasi nuo futbolininkių ($p < 0,001$).

Judėjimo vertikalia kryptimi kinematinių, kinetinių ir antropometrinių rodiklių koreliacinė analizė parodė, kad svarbiausi rodikliai, pagal kuriuos objektyviausiai galima įvertinti žaidėjų judėjimo galimybes, yra KMI, atsispyrimo trukmė, polėkio ore trukmė ir šuolių aukštis, absoliuti jėga ir santykinis galingumas, kūno judėjimo greitis, jėgos augimo greitis, reaktyvumas.

Raktažodžiai: krepšininkės, futbolininkės, tinklininkės, antropometriniai, kinematiniai ir kinetiniai rodikliai, vertikalus šuolis, koreliacija.

Darius Radžiukynas
Lietuvos edukologijos universiteto
Sporto ir sveikatos fakulteto Sporto metodikos katedra
Studentų g. 39, LT-08106 Vilnius
El. p. darius.radziukynas@leu.lt
Mob. +370 651 25 328

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