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Lower extremity power in female soccer athletes: a pre-season and in-season comparison

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Purpose: Lower extremity power is an important physical capacity of a soccer athlete. Power represents, and can be modified by, the training of strength and speed. Pre-season and in-season training differs in the relative emphasis on these two quantities. It is nevertheless desirable that the mechanical power remain the same or become higher during the in-season period. The purpose of this study was to identify changes in quantities related to "explosive strength" and to check whether, in collegiate female soccer players, pre- and in-season lower extremity power will remain unaltered.

Methods: Twenty collegiate female soccer players, representing all field positions, participated. Lower extremity power was assessed by a series of drop jumps executed from four different heights (15, 30, 45, and 60 cm). Mechanical power was calculated using subject's mass, jump height, and acceleration due to gravity. This value was further normalized by body mass of each athlete to obtain the relative (or normalized) mechanical power.

Results: The normalized lower extremity mechanical power was highest when landing from the 30 cm height for both pre- and in-season periods. However, contrary to expectations, it turned out lower during the in-season than during the pre-season test, even though no significant differences were found between the corresponding jump heights.

Conclusions: It is concluded that altered, perhaps inadequate, training strategies were employed during the in-season period. Besides, advantages of adding the relative mechanical power as a season readiness indicator are underlined compared with relying on the jump height alone.

Key words: *countermovement jump, drop jump, plyometric training, relative power*

1. Introduction

Strength and speed are important components of an athlete's preparation for real world competition in many ball game sports. In soccer, one of the most efficient ways to influence a player's performance is by enhancing the power produced by his or her lower limbs. This can be accomplished by choosing an appropriate volume and intensity of strength and speed training, for which biomechanical monitoring has proven to be useful. The popularity of soccer as a recreation and competitive sport inspired a number of research studies tackling issues concerned with efficiency, biomechanical properties of specific movement tasks, as well as soccer training programs and their contents. Lees and Nolan [9] provided a comprehensive review of various approaches to these concepts.

The process of mastering and efficiently applying typical soccer skills requires adequate neuro-muscular preparation, for which plyometric training can be helpful. It is known that plyometric training improves the ability of the lower limbs to generate power (i.e., the ability to execute large amounts of mechanical work within a short time, sometimes also called explosive strength) [3]. A large lower extremity power is very useful in many instances during a soccer game,

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as for example short sprints, jumping for a header or goalkeeper jumping. Those aspects of training which improve the power of the lower limbs and impact the efficiency of kicking the ball in female soccer players were investigated by Campo et al. [3] and Rubley et al. [14]. Plyometric training aims also at improving the efficiency of the stretch–shortening cycle of skeletal muscles, including the ability to use/reuse the potential energy of elasticity [11], [12]. Moreover, Hewett et al. [5] pointed out the importance of plyometric exercises for lowering the risk of injuries in female soccer players.

A good test providing information about the level of the lower limbs' power of a player is the countermovement jump (CMJ) [17]. A different test was introduced by McClymont and Hore [10] who employed DJ jumps for controlling rugby players' plyometric training [2]. The efficiency of movement was described by the quotient of jump height and contact time (amortization phase and push-off phase taken together) which they named the "Reactive Strength Index" (RSI) and expressed in meters per second. Reaching a particular value of this index served to evaluate a player's level of power of the lower limbs. It additionally provided information about the preparation for the in-season (competitive season) and was an indication of the loads applied in the plyometric training program. The RSI Index was also used for evaluating the power of the lower limbs in basketball players. The results pointed towards the possibility of using this information for programming load levels in plyometric training [1], [2].

Pietraszewski and Rutkowska-Kucharska [13] modified the RSI Index by assuming that the "reactive strength index" would be better expressed by referring the DJ jump height not to the whole contact time (i.e., weight acceptance phase plus push-off phase), but instead to the push-off duration alone. An advantage of this change was that thus defined ratio became closely related (by a factor of g, the acceleration due to gravity) to the relative power during push-off (P_{rel}), where relative meant related to unit of mass.

Training accents change during a year long training cycle. Different roles are played by the pre-season and in-season parts of it. During the pre-season, in soccer, more stress is placed on development of strength and the so called explosive strength (power), which is the primary outcome of plyometric excercise. In the in-season, training accents change to include more specific soccer drills and game formation, ideally without losing the previously achieved levels of power. It would therefore be interesting to see to what extent this aim can be reached. That is why the objective of this investigation was to identify changes in quantities related to explosive strength and to check whether the index of relative mechanical power (P_{rel}) would remain unaltered between the two subsequent training periods, the pre-season and the in-season.

2. Materials and methods

Twenty collegiate female soccer players were recruited for this study. They were all members of the AZS Wrocław club, currently in the Polish Women's Extra League, and represented the following field positions: 2 strikers, 8 midfielders, 7 defenders, and 3 goalkeepers. They were aged 24.5 ± 2.3 years and their training experience was on average 8.15 ± 2.18 years, comprising the range from 4 to 16 years. Average body mass and height of the subjects was 58.8 ± 3.0 kg and 164.9 ± 3.4 cm, respectively. Because of injuries and transfers to other clubs, only 15 players out of the initial 20 participated in the full set of tests. The tests were carried out in the certified Laboratory of Biomechanical Analyses (Quality Management Certificate ISO 9001:2009) of the University of Physical Education in Wrocław, Poland, following approval by this school's Research Ethics Committee. Each participant signed an informed consent statement.

The tests were carried out twice in 2012, in accordance with the training cycle. The first set was carried out within the pre-season period (February of 2012) and the second within the in-season (competitive) period, which started in May of the same year. This second testing session took place in the 5th week of the in-season, after 3 competitive matches. All tests were carried out before a day's training. The first training period (pre-season) was a mezocycle aimed at specific performance, with microcycles focused on anaerobic (speed) endurance, co-ordination (especially dynamic balance and rhythmization), functional strength, and technical and tactical training of co-operation within offensive and defensive formations. In the second, in-season mezocycle, the players trained to maintain their high motor performance, with emphasis placed in microcycles on speed, speed edurance and strength, and game control skills practiced through co-operation within different formations of the 1:4:4:2 system (goalkeeper:defenders:midfielders:strikers), including different game schemes, set games, zone defence, and wing attack.

The subjects were asked to execute vertical countermovement jumps (CMJ) and drop jumps (DJ) from initial heights of 15 cm, 30 cm, 45 cm, and 60 cm (Fig. 1). Each jump was repeated thrice and only the highest one out of the three was selected for further analysis.

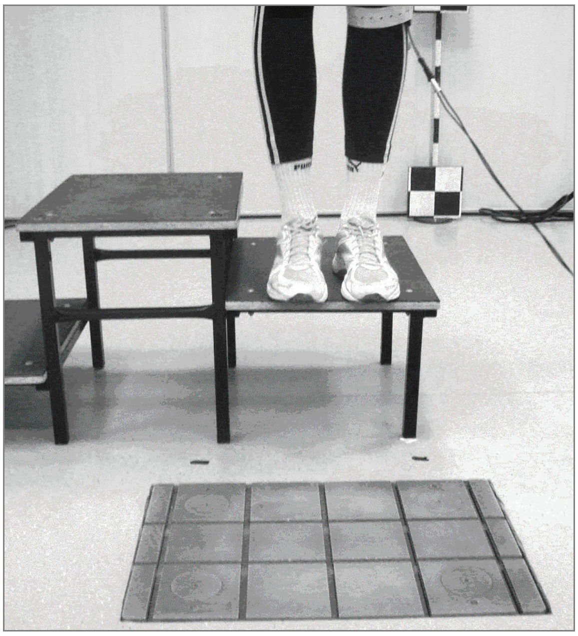

Fig. 1. Drop jump (DJ) laboratory testing set-up

Prior to the series of jumps a 10-minute-long warm-up was administered, which included jogging, series of hops, and rehearsing of drop jumps. To avoid a possible negative impact on the results of vertical jumps, attention was paid not to include any static stretching exercises in the warm-up [19].

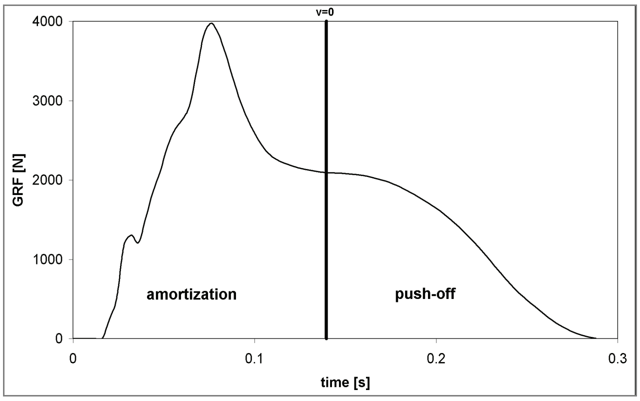

Fig. 2. Vertical ground reaction force during a drop jump (DJ). Vertical line designates end of weight acceptance (amortization) and beginning of push-off

The ground reaction force was recorded during each jump by using a force plate (Kistler 9281B13, Switzerland). The whole contact phase was then divided into the weight acceptance (amortization) phase and the push-off phase with respective durations t_a and t_p (Fig. 2). To this end, we found the time at which velocity changed direction as the time necessary to brake the impulse of the body gained during free fall from the initial height of the drop jump. This required integration of acceleration, determined by the difference between GRF and body weight, with the value of velocity at the beginning of the contact phase as the initial condition.

The records of the ground reaction force were also used to evaluate the heights of the jumps. For this purpose, the impulse was first found by integrating the quantity $F_r(t) - mg$ over the push-off phase,

$$J = \int_{t_0}^{t_1} (F_r(t) - mg)dt ,$$

and then – making use of the relationship between impulse and change of momentum – the take-off velocity (v_0) was calculated using the equation

$$v_0 = \frac{J}{m} ,$$

where J – resultant vertical impulse, m – mass of the subject.

Assuming that the flight phase of a jump can be thought of as a vertical projectile motion, the height of the jump (h) can be evaluated

$$h = \frac{v_0^2}{2 \cdot g} ,$$

where v_0 – take-off velocity, g – acceleration due to gravity.

The mechanical work (W) performed during the push-off phase was next evaluated. It consists of two parts: the work performed by the subject to increase their kinetic energy, ΔE_{kin}, and the work performed to increase their gravitational potential energy, ΔE_{pot}. The former can be evaluated as the kinetic energy at take-off: $\frac{1}{2} m \cdot v_0^2$; the latter requires information on the vertical distance, h_p, covered by the subject's center of mass during the push-off phase: $m \cdot g \cdot h_p$. We found this distance by double integration of the vertical component of acceleration of the subject's center of mass, i.e., the vertical component of the resultant force acting on their body divided by their mass, $(F_r(t) - m \cdot g)/m$, over a time interval corresponding to the push-off phase. Similar subject's body positions while starting the drop and at the first contact with the ground were assumed.

Mechanical power (P) was then calculated by dividing the mechanical work by the push-off time (t_p), and this quantity was then divided by the subject's mass to obtain the relative mechanical power (P_{rel})

$$P_{rel} = \frac{v_0^2 + 2 \cdot g \cdot h_p}{2 \cdot t_p} = \frac{2 \cdot g \cdot h + 2 \cdot g \cdot h_p}{2 \cdot t_p} = \frac{g \cdot (h + h_p)}{t_p}.$$

To assess the amount of change in the variables obtained from drop jumps starting from four different heights we compared their means in the pre-season and in the in-season. In each comparison there was one binary independent variable (time with two discreet values, pre-season and in-season) and one continuous dependent variable – jump height (h), push-off time (t_p), or relative mechanical power (P_{rel}). The Shapiro–Wilk test was used to confirm normality of the pre-season and in-season data corresponding to these variables. As in each of the comparisons the same group of 15 subjects was tested twice, pre-season and in-season, we assessed differences between means using repeated measures (paired) Student's t-test with 14 degrees of freedom. The significance level was set at $\alpha = 0.05$. Besides, Cohen's d effect size was estimated for each comparison.

3. Results

Average CMJ heights achieved by the examined players were 0.281 ± 0.04 m in the pre-season and 0.265 ± 0.03 m in the in-season, and this difference turned out statistically nonsignificant. Such small jump heights suggest a very low level of the related ability, both in the pre-season and in the in-season mezocycle [17].

Table 1. Means and standard deviations (X ± SD) of drop jump (DJ) heights (h) following drop from different initial heights. Data were collected in the pre-season (PS) and in the in-season (IS) of the soccer training cycle. Student's t-test values t (paired) and p (two-tailed) are reported together with Cohen's effect size d

14 degrees of freedom	Initial heights (cm)			
	15	30	45	60
h (m) – PS	0.256 ± 0.050	0.258 ± 0.047	0.260 ± 0.044	0.254 ± 0.053
h (m) – IS	0.259 ± 0.038	0.264 ± 0.044	0.260 ± 0.039	0.249 ± 0.040
t	–0.31	–0.73	–0.057	0.65
p	0.76	0.48	0.96	0.53
d	0.08	0.19	0.015	–0.17

Table 2. Means and standard deviations (X ± SD) of the push-off time (t_p) following drop landing from different initial heights in the pre-season (PS) and in the in-season (IS) of the soccer training cycle. Student's t-test values t (paired) and p (two-tailed) are reported together with Cohen's effect size d (its values conventionally deemed to be large are shown bold and underlined). Drop heights for which significant ($p \le 0.05$) change was found are marked with an asterisk

14 degrees of freedom	Initial heights (cm)			
	15*	30*	45	60
t_p (s) – PS	0.166 ± 0.030	0.153 ± 0.036	0.159 ± 0.033	0.162 ± 0.031
t_p (s) – IS	0.196 ± 0.051	0.182 ± 0.047	0.174 ± 0.042	0.182 ± 0.052
t	–2.58	–3.06	–1.31	–2.02
p	0.022	0.0086	0.21	0.063
d	0.67	**0.79**	0.34	0.52

Table 3. Means and standard deviations (X ± SD) of the lower extremity mechanical power (P_{rel}) estimated during the push-off phase following drop landing from different initial heights in the pre-season (PS) and in the in-season (IS) of the soccer training cycle. Student's t-test values t (paired) and p (two-tailed) are reported together with Cohen's effect size d (its values conventionally deemed to be large are shown bold and underlined). Drop height for which significant ($p \le 0.05$) change was found is marked with an asterisk

14 degrees of freedom	Initial heights (cm)			
	15	30*	45	60
P_{rel} (W/kg) – PS	31.72 ± 6.33	32.61 ± 5.02	30.75 ± 5.79	28.79 ± 6.13
P_{rel} (W/kg) – IS	28.26 ± 5.95	28.56 ± 5.19	28.40 ± 5.96	26.01 ± 3.73
t	1.77	3.95	1.65	1.76
p	0.099	0.0015	0.12	0.1
d	–0.46	**–1.02**	–0.43	–0.45

On average, the highest DJs were performed following drop from an initial height of 45 cm in the preseason and 30 cm in the in-season (Table 1), but generally DJs from different individual initial heights differed only slightly. Considered timewise, DJ heights in the pre-season and in the in-season mezocycles turned out to be not significantly different ($p \geq 0.48$) with small corresponding values of Cohen's effect size $-0.17 \leq d \leq 0.19$.

Significantly shorter ($p = 0.0086$) durations of the push-off phase t_{p} in the pre-season mezocycle compared with the in-season mezocycle were found for the examined players in DJs from the initial height of 30 cm (Table 2), which could also be judged from the large corresponding value of Cohen's effect size $d = 0.79$. In the pre-season, the mean push-off time was the shortest in DJs executed from the initial height of 30 cm, and this minimum was shifted to the next initial height of 45 cm in the in-season. Similar but slightly larger values of t_{p} were found in DJs from the other initial heights, but they increased to a lesser degree between seasons.

The relative mechanical powers (P_{rel}), which are shown in Table 3, displayed a related behavior. This could be expected due to an approximately reciprocal relationship between the push-off time and the relative power. At the initial height where t_{p} was the shortest (30 cm) the relative mechanical power was indeed the largest in the pre-season. In the in-season, however, this maximum occurred at the same initial height of 30 cm and not where the push-off time had its minimum (45 cm). Both in terms of statistical significance and effect size, the largest between-season differences of the relative mechanical power were found for the initial height of 30 cm: significance with $p = 0.0015$, Cohen's effect size $d = -1.02$.

4. Discussion

The objective of this study was to determine if, in collegiate female soccer players, the pre- and in-season lower extremity power would remain unaltered despite different training protocols applied in these periods. To quantify the possible differences, the CMJ and DJ heights as well as DJ relative mechanical power were used to monitor the speed-strength characteristics of each player. In the pre-season period, a significant component of the training activities was devoted to enhancing the athlete's rate of force development. This characteristic, among others, is necessary to execute a powerful shot, to quickly change position, to jump up towards the ball, or to quickly change direction of movement.

No statistically significant drop was found for CMJ and DJ heights in the in-season period compared with the pre-season period. These quantities remained therefore unchanged over both training mezocycles. By contrast, the relative mechanical power tended to decrease (most notably at the initial height of 30 cm: significance with $p = 0.0015$ and Cohen's effect size $d = -1.02$, Table 3) while the push-off time tended to increase (again, most notably at the initial height of 30 cm: significance with $p = 0.0086$ and Cohen's effect size $d = 0.79$, Table 2), which may have to do with the approximately reciprocal relationship between these two quantities.

The importance of the relative mechanical power is mainly in providing a shorter transition phase between weight acceptance and push-off in the DJs. It can therefore be assumed that the ability to re-utilise potential elastic energy of the lower extremity muscles engaged in the stretch-shortening cycle deteriorated in the in-season compared with the pre-season period. This may point to inadequate volumes of strength and speed training; perhaps simply using too much high load training and too little plyometric exercise. Another cause of the drop of the relative mechanical power in the in-season period could be that specific soccer exercises may have decreased the ability to jump efficiently. Besides, it is also possible that an increased level of fatigue caused by the ongoing competitive season (in-season) may have unfavorably influenced the efficiency of elastic energy recuperation in the stretch-shortening cycle [12]. Finally, since data collection took place only once, there could have been an impact of prior rest or fatigue that had influenced the results.

Comparing our results with those obtained by other investigators, female basketball players tested by Kellis et al. [6], being of similar age compared to the soccer players participating in this study, achieved average heights of CMJ and DJ40 equal to 0.29 m and 0.293 m, respectively. According to a study by Laffaye and Choukou [8], female volleyball players also turned out better than our subjects: they achieved average heights of DJ30 and DJ60 equal to 0.363 and 0.357 m, respectively, and their relative mechanical power revealed in these jumps equaled 41.7 and 43.1 W/kg. This trend is further corroborated by comparisons with female competitors representing several other sports disciplines [16]. The lesser results achieved by the soccer players tested in our study seem to confirm a general notion that not enough importance is attributed in training to the vertical jump in those disciplines in which this element is not deemed crucial. To change this practice, the role of the vertical jump in the training program should perhaps be seen as a way to generally improve the speed-strength abilities and not just to learn how to jump higher.

Differences between disciplines and consequently different training objectives should of course be taken into account. For example, it was estimated that the average number of jumps executed by one female soccer player of the AZS AWF Wrocław club during a match in the season of 2011/2012 was only 3.7 (unpublished information). However, this does not lessen the purport of the final conclusion that the ability of producing high mechanical power of the lower limbs was too low in the investigated group of players. The power of the players' lower limbs is generally thought to be shaped by using plyometric exercises during the pre-season period, and these exercises were not sufficiently emphasized in their training program.

Soccer is based on explosive movements such as shots, sudden starts, and short distance sprints. Despite the fact that vertical jumps can also be included into this category of movements, soccer players often find it difficult to execute them properly [7].

Beside soccer, DJ jumps results and the RSI index calculated based on them were used to monitor and control individual training loads in a plyometric training program of rugby players in New Zealand [10]. For example, if a player achieved their maximal DJ performance when using an initial drop height of 30 cm, then their next recommended training stage should include drop jumps from 45 cm.

Considering its role in training protocols, plyometrics are often erroneously associated with improving only the ability to jump high. This is at least what could be superficially inferred from regarding its basic exercise, i.e., the DJ. In reality, however, this type of training is in fact aimed at shaping the power of the lower extremities, which is a feature very desirable in team games [2]. For example, the ability to develop higher mechanical power (which is the product of velocity and force) while kicking the ball will allow a "faster and stronger" shot. As a consequence, even though soccer players execute a relatively small number of jumps compared with other disciplines (during a game, a basketball player jumps, on average, 4.9 to 6.6 times per minute [15], compared with only 3.7 per game for a female soccer player of the tested group), using elements of plyometrics in soccer training should be definitely recommended. Plyometric training also influences favorably the so called dynamic balance ability, whose higher level may help prevent injuries during training and competition [18].

We must be mindful that it is the right proportion of strength and speed exercises that shapes the ability to execute explosive movements [5]. It is therefore extremely important to properly choose the load for every single exercise and every single athlete. Chimera et al. [4] recommend the inclusion of plyometric exercises in training programs of female soccer players because it lowers the risk of injury through improvements of dynamic balance. According to these authors, this benefit alone is so valuable that plyometric training should not be abandoned even when there is no clear progress regarding the other functions of the lower limbs.

Given the relatively high incidence of lower limb injuries in soccer, using training protocols that lower the risk of injuries (including non-contact injuries) seems highly recommended [5]. This becomes even more important in the case of female athletes, because they are generally more prone to injury than their male colleagues [20]. Besides, plyometric training programs devised to prevent lower limb injury result in improving other important features like power, strength, speed, and quality of movement execution, which has been proven for young female players representing a variety of team games, including soccer [11].

Summing up, there was no difference in CMJ and DJ heights when tested pre-season and in-season among collegiate female soccer players. By contrast, a drop of the relative mechanical power was revealed in DJ and an increase of the push-off time occurred in the in-season as compared to the pre-season. A deterioration of the players' speed-strength abilities, which are crucial in soccer, was observed. Lower values of the relative mechanical power (and longer push-off times) in the in-season period may have resulted from an inappropriate ratio of strength and speed training during the pre-season training. Attempting a physiological interpretation, this could be attributed to muscles' diminished load tolerance accompanied by lowered efficiency of the stretch shortening cycle and consequently a worse reutilization of the elastic potential energy. In practical terms, we have noted differences in the weekly training program. In the pre-season, strength and speed-strength practice was most emphasized, whereas in the in-season, when competition started, the soccer skills and game formation practice prevailed.

It may be worthwhile to note the different but complementary diagnostic functions of the countermovement jump (CMJ) height and the relative mechanical power developed in drop jumps (DJs). The CMJ provides basic and quick information on the jumping potential of an athlete. By contrast, the relative mechanical power expressed in a DJ is an individualized measure that describes an athlete's speed-strength potential and can facilitate the choice of individual loads in plyometric training. This suggests the use of this quantity beside and independently of the information gathered from the CMJ tests.

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References

[1] BOBER T., RUTKOWSKA-KUCHARSKA A., PIETRASZEWSKI B., LESIECKI M., *Biomechanical criteria for specifying the load applied in plyometric training in basketball*, Research Yearbook, 2006, Vol. 12(2), 227–231.

[2] BOBER T., RUTKOWSKA-KUCHARSKA A., PIETRASZEWSKI B., *Plyometric exercises – biomechanical characteristics, indexes, applications*, Sport Wyczynowy, 2007, Vol. 7–9, 511–513.

[3] CAMPO S.S., VAEYENS R., PHILIPPAERTS R.M., REDONDO J.C., DE BENITO A.M., CUADRADO G., *Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players*, J. Strength Cond. Res., 2009, Vol. 23(6), 1714–1722.

[4] CHIMERA N.J., SWANIK K.A., SWANIK C.B., STRAUB S.J., *Effect of plyometric training on muscle-activation strategies and performance in female athletes*, J. Athl. Train, 2004, Vol. 39(1), 24–31.

[5] HEWETT T.E., LINDENFELD T.N., RICCOBENE J.V., NOYES F.R., *The effect of neuromuscular training on the incidence of knee injury in female athletes: a prospective study*, Am. J. Sports Med., 1999, Vol. 27(6), 699–706.

[6] KELLIS S.E., TSITSKARIS G.K., NIKOPOULOU M.D., MOUSIKOU K.C., *The evaluation of jumping ability of male and female basketball players according to their chronological age and major leagues*, J. Strength Cond. Res., 1999, Vol. 13(1), 40–46.

[7] KOTZAMANIDIS C., CHATZOPOULOS D., MICHAILIDIS C., PAPAIAKOVOU G., PATIKAS D., *The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players*, J. Strength Cond. Res., 2005, Vol. 19(2), 369–375.

[8] LAFFAYE G., CHOUKOU M.A., *Gender bias in the effect of dropping height on jumping performance in volleyball players*, J. Strength Cond. Res., 2010, Vol. 24(8), 2143–2148.

[9] LEES A., NOLAN L., *The biomechanics of soccer: a review*, J. Sports Sci., 1998, Vol. 16(3), 211–234.

[10] MCCLYMONT D., HORE A., *Use of the Reactive Strength Index RSI as a plyometric monitoring tool*, Proceedings of the 5th World Congress of Science in Football, Lisbon, 2003.

[11] MYER G.D., FORD K.R., PALUMBO J.P., HEWETT A.E., *Neuromuscular training improves performance and lower-extremity biomechanics in female athletes*, J. Strength Cond. Res., 2005, Vol. 19(1), 51–60.

[12] OLIVER J., ARMSTRONG N., WILLIAMS C., *Changes in jump performance and muscle activity following soccer-specific exercise*, J. Sports Sci., 2008, Vol. 26(2), 141–148.

[13] PIETRASZEWSKI B., RUTKOWSKA-KUCHARSKA A., *Relative power of lower limbs in drop jump*, Acta Bioeng. Biomech., 2011, Vol. 13(1), 13–18.

[14] RUBLEY M.D., HAASE A.C., HOLCOMB W.R., GIROUARD T.J., TANDY R.D., *The effect of plyometric training on power and kicking distance in female adolescent soccer players*, J. Strength Cond. Res., 2011, Vol. 25(1), 129–134.

[15] STONKUS S. *Basketball – History, Theory, Didactics*, Lietuvos Kuno Kulturos Akademija, 2003.

[16] STRUZIK A., PIETRASZEWSKI B., *Examination of the relationship between the static moment of force and the height of counter movement jump (CMJ) by using modern measuring devices*, Acta Bio-Optica et Informatica Medica, 2010, Vol. 16(4), 346–350.

[17] TRZASKOMA Z., TRZASKOMA Ł., *Strength and power in elite male and female players engaged in team sports*, Acta Bioeng. Biomech., 1999, Vol. 1(suppl. 1), 519–522.

[18] VALOVICH MCLEOD T.C., ARMSTRONG T., MILLER M., SAUERS J.L., *Balance improvements in female high school basketball players after a 6-week neuromuscular-training program*, J. Sport Rehabil., 2009, Vol. 18(4), 465–481.

[19] VASCONCELLOS F.V.A., DE SALLES P.G.C.M., ACHOUR JUNIOR A., DE MELLO D.B., DANTAS E.H.M., *The vertical jump height of soccer players after static overstretching*, Hum. Mov., 2012, Vol. 13(1), 4–7.

[20] WALDÉN M., HÄGGLUND M., WERNER J., EKSTRAND J., *The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective*, Knee Surg. Sports Traumatol. Arthrosc., 2011, Vol. 19(1), 3–10.