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THE INFLUENCE OF EXTERNAL AND INTERNAL FACTORS ON THE SQUAT JUMP HEIGHT

Dragan Klisarić

Faculty of Sport and Physical Education, University of Belgrade, student of MAS, Serbia

Abstract
Squat jump is an important tool - an exercise that determinespower of kinetic chain muscle groups which leads to jump height. Science and practice registered numerous factors that influence the squat jump height, the most important are set out and described. The aim of this article was to describe and explain the influence of external and internal factors on the squat jump height. The paper compares and comments on the results of available domestic and foreign scientific research. The analysis of the researched sources concluded that the greatest influence on the squat jump height among the external factors has the way of performance, while the greatest influence among internal factors has growth. The results of this article can be used to improve the quality of directing and abilities testing as well as the training process to achieve the best in sports and sports branches.

Keywords: MOTOR ABILITIES / DIFFERENCE / GROWTH/ SEX

Correspondence to author: Dragan Klisarić E-mail: dklisaric94@gmail.com

INTRODUCTION

Contemporary sport requires implementation of sports training in a quality way to develop the abilities of athletes and achieve the best possible success in the competition. To achieve this goal in an efficient and safety way, a lot of efforts, willpower, knowledge and other resources need to be invested. In accordance with the specifics of the movement of a particular sport and sport branches,numerous exercises are used in training. Squat jump (SJ) is an exercise used in sports training to develop and monitor an athlete's abilities. There are a numerous factors that influence the squat jump height and are often the subject of scientific research.

Analyzing different informational sources it is noticed that there are numerous determinants of factors that influence SJ. The sources are scientific papers, published in international and domestic journals, categorized in M22, M53 and others.For the purposes of this article, the term factor is defined as a circumstance, fact or influence that contributes to the result. In scientific research, factors are independent variables that can be controlled by the design of the study. Factors, as independent variables, can influence phenomena, states, or processes, which we call dependent variables that change, qualitatively or quantitatively, to the extent of the influence of independent variables. Factors can exert influence individually, what we call monocausality or contingent that is, combined by several factors, which we call multicausality.

In scientific research, factors are size, which is characterized by qualitative and especially quantitative dimensions such as volume (quantity), intensity (magnitude), the duration of the influence exerted, the speed of expression, the direction of influence, valence, etc. Factors can exert influence of varying degrees of intensity: small, medium, and large influence, including the degree of complete determinism, according to which the observed factor has a complete and, under certain conditions, a necessary and exclusive influence. On the same phenomenon or process, simultaneously or successively only one factor or multiple factors can influence, whereby the intensity of influence is conditioned by the relationships and interactions between the factors themselves. In such multifactorial, contingent influence, one and the same factor may influence to a greater or lesser extent the observed phenomenon, depending on the cooperation with other influential factors (e.g. motivation to train in interaction with the air temperature in the gym, the quality of sports equipment, behavior trainers etc).

The most common division of factors in scientific research is to external and internal. According to the factor classification of the drop jump in the Matic study (2016a), a similar classification of the factors was defined in this paper for the squat jump.This division was performed according to the criterion of affiliation of factors to external, i.e. objective environment (environment) or internal, i.e. participative (personal). In this article, the most important external factors are considered: type of training load, way of performance, and ergogenic aids, as well as internal: neuromuscular fatigue, growth, and sex.

The research problem in this article can be formulated in the form of a complex problem question that reads: What factors exert influence on the squat jump height, as well as which factors have the greatest influence and is there any contingent (combined) influence among them? The subject of the article are external and internal factors, the squat jump and the influence of the factors on the squat jump height. The aim of the article was to describe and explain the influence of external and internal factors on the squat jump height, as well as to determine which factors have the greatest influence and whether there is a combined influence between them.

EXTERNAL FACTORS THAT INFLUENCESQUAT JUMP HEIGHT

Squat jump height and type of training load

To improve the abilities of athletes, various types and methods of mechanical loading are used in training, such as weightlifting, plyometric training, explosive method, and many others. The right choice and combination of loading factors, depending on the athlete individual status, requirements of the sport itself, and competitive discipline... will produce results of training which lead to improvedabilities of the athletes.

In a 10-week study by Wilson et al. (Wilson, Newton, Murphy & Humphries, 1993), the goal was to compare the effects of three different training loadingmethods: weightlifting, plyometric method, and explosive method. Sample of 64 participants who had at least one year of training experience and were able to lift a load greater than their body weight (BW) in the half squat exercise participated in the study. The participants were randomly divided into three experimental groups according to the above training load methods and into a control group. Also, it is important to note that there were no differences between the groups of participants in comparison of anthropometric characteristics and measured abilities before the start of the program. The group that implemented the explosive training method performed a squat - jump exercise with additional external load, which allowed the maximum power exertion. The squat - jump exercise is always performed in the Plyometric Power System (Plyopower Technologies), which determined the angle in the knee joint from 2.1 to 3.14 rad. for the static position. The load for each work set was adjusted to enable each participant approximately 30% of the measured maximum isometric force. This load was adjusted as participants progressed over 10 weeks. The results of Wilson et al. (1993) study show that the group that conducted the explosive training method achieved a jump height of 33.8 cm before the start of the program; during the program (4 weeks) 37.8 cm and after eight weeks38.8 cm. It also shows that the group that applied the explosive training method significantly improved the jump height compared to the other groups that implemented different experimental training load methods, as shown in Table 1. It can also be observed that a significant improvement is achieved after five weeks for 5 cm, followed by a plateau.

Table 1 Results of the squat jump test: before, during, and after 10 weeks of the training program

Groups	Measuring		
Maximal squat jump height (cm)	Pre	Mid	Post
Control group	35.9	35.1	35.8
Weight lifiting group	38.0	39.3	40.4
Plyometric group	35.6	36.2	37.9
Maximum power group	33.8	37.8	38.8

Based on the study described, it can be concluded that the nature offactor type of training load, more specifically the explosive training method, significantly influences the increase of the squat jump height compared to the plyometric training method and weightlifting.

In a recent study in a period of eight weeks by Vanderka et al. (Vanderka, Longová, Olasz, Krčmár & Walker, 2016), the goal was to examine whether a squat jump with individually determined workload could simultaneously improve several abilities as well as the squat jump height. The above exercise represents an explosive method of training. The exercise is performed by placing the loaded bar on the participant's shoulders, then he squats, after which he quickly extends joints of his legs and torso and leaves the ground. The workload magnitude used in this exercise seems to be critical to the outcome of the training. Specifically, training with a lighter load will improve strength at high movement speed, i.e. near the end of the force - velocity curve; while high-load training will improve strength at high muscular strength (low movement speed), ie. at the end of the force-velocity curve (McBride, Triplett-McBride, Davie, &Newton, 2002; Smilios, Sotiropoulos, Christou, Douda, Spaias &Tokmakidis, 2013 as cited in Vanderka et al., 2016). The study included moderately trained Faculty of Sport and Physical Education students with at least two years of strength training experience. The eight-week load used was determined from the measurement of the power exerted in the test with a progressive increase in load in the squat-jump exercise with a bar on the shoulders. The starting load was 20 kg, then increased for 10 kg after each set. The load at which the maximum power plateau (Pmax) appeared was the required individualized workload for the training program. Strength, power and speed were measured by a linear transducer of the Fitronic brand. The experimental group performed a squat - jump exercise with a predetermined load in the test. During the eight weeks, thirteen workouts were carried out with 8 sets of 4 repetitions with a load that allows the maximum power to be exerted and 13 trainings with 4 sets of 8 repetitions with a load that enables the exertion of 80% of the maximum power. Jump height was measured using the Myotest system, which measures jump height through position change in the vertical axis.

The results ofVanderka's study (2016) showed that after applying the explosive training method for eight weeks, the experimental group achieved a squat jump height of 39.3 cm before the start of the program, during the program 45.3 cm and after the program 45.4 cm, which indicates a significant improvement over the control group, as shown in Table 2. In addition, it can be observed that after four weeks (during) the study, the jump height improves by 6 cm, followed by a plateau.

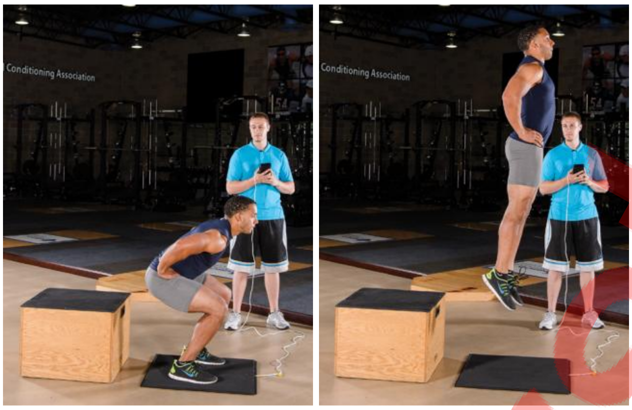
Table 2 Average values of experimental and control group of squat jump height: before, during and after eight weeks of the study (Vanderka et al. 2016)

Test	Experimental group			Control group		
	Pre	Mid	Post	Pre	Mid	Post
Squat jump (cm)	39.3	45.3	45.4	41.3	40.6	41.8

The findings of the aforementioned studies indicate that the type of training load factor (explosive training method) significantly influences the increase of squat jump height in a short period of four and five weeks for participant groups in analyzed studies. However, limitations in concluding exist, because there are differences in the approach of determining the optimal training load between studies. In the first study, the load was determined on the basis of the maximum isometric force, while in the second study, the load was determined on the plateau in the expression of maximum power (Pmax).

Way of performance and squat jump height

Squat jump is performed from a static position by lowering body from an upright position to a squat position with flexion in the ankle, knee (90° angle) and hip joint. This position participant holds for 2 to 3 seconds. Then the maximum jump is performed (Figure 1). This jump excludes the activation of the stretch and shortening cycle of the muscle, and the jump is accomplished only on the basis of concentric muscular contraction. Compared to the drop jump and the countermovement jump, the squat jump results in lower jump heights. This jump can be useful for sports and sports branches where eccentric contraction is not preceded, but concentric contraction is exerted from isometric conditions, such as swimming start from starting block, a block in volleyball, jumping under basket in basketball, ski jumping, etc.



a b

Figure 1 Variations of squat jump: a - starting position, b - maximum jump (Haff &Triplet 2016)

Most jumps in daily and sports activities are performed with the rapid swing of the arms which is synchronized together with the movement of the legs, which all lead to improved jump height. Also, in sports activities a one-leg jump (unilateral) is often performed, which is explained in further text.

In Hara et al. (Hara, Shibayama, Fukashiro, 2006) study, the goal was to examine how arm swing affects leg strength and work during vertical jump and to gain insight into how arm swing can increase jump height. Participants performed a squat jump without arm swing and a squat jump with arm swing (Figure 2). The results of the study based on the movement of the center of gravity of the body show a higher squat jump height with a swing of arms of 56 cm compared to the squat jump height without swing of the arms of 46.2 cm, which is a significant difference.

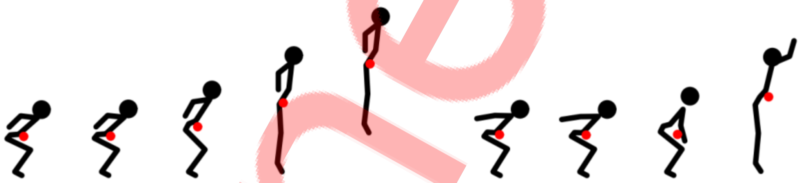


Figure 2 Variations of performance: SJ –withouthands swing; (b) SJA – with hands swing (Hara, Shibayama, Fukashiro, 2006)

Hara et al. (2006) research shows that a squat jump with arm swing raises the center of gravity of the body more than a squat jump without arm swing by 9.8 cm, and also contributes to an increase in the total engagement of the ankles, knees and hips.

In several studies, the height of the jump with both legs (bilateral) was found to be less than the sum of the height of the twice performed jump on one leg (unilateral). This indicates a bilateral deficit (BLD). Bobbert et al. (Bobbert, de Graaf, Jonk & Casius, 2006) explain this phenomenon as a deficit in the mechanical output of the legs individually when jumping with both legs at the same time relative to the jump on one leg separately.

In sports, different procedures and tests are used to improve the abilities or recovery of athletes. Measuring bilateral asymmetry (muscle imbalance) of legs helps prediction and possible injury prevention.Loturco et al. (Loturco, Pereira, Kobal, Abad, Komatsu, Cunha & Cohen, 2018) tested top athletes - soccer players in the squat jump with both legs and the squat jump on one leg. All jumps were performed with hands on hips. The results showed that the participants achieved an average height of 33.9 cm in the squat jump with both legs (bilateral), while on average they achieved a squat jump height of 17 cm on one leg (unilateral). It is evident that higher jump height is achieved when the squat jump is performed with both legs at the same time by 16.9 cm. The application of the squat jump helps to detect bilateral asymmetry, which can be further influenced by various training procedures (e.g. unilateral exercises) in order to achieve muscular balance, and to improve abilities but also to prevent possible injuries.

In the study of Psycharakis et al. (Psycharakis, Eagle, Moir, Rawcliffe, Mckenzie, Graham... & Connaboy, 2019), the aim was to examine the effect of additional load on the occurrence of bilateral deficit in the squat jump. Sample of 40 recreationally trained men participated in the study. All participants performed a squat jump with both legs, a left-leg jump and a right-leg jump. Also, these jumps were performed without additional load and with an additional load of 10% of the total BW. All the jumps were performed without arm swing, holding the hands on the hips. In the test without additional load, participants in average achieved a jump height of 26 cm on the left leg, 25 cm on the right, making a sum of 51 cm, while on both legs they achieved height of 44 cm. Then, in the test with additional load, participants in average achieved squat jump height on the left leg 23 cm, on the right 23 cm, making a sum of 46 cm, while on both legs they achieved height of 41 cm.

The study of Psycharakis et al. (2019) shows that a bilateral deficit exists and that jump height values are higher under conditions without additional loading. The squat jump height from both legs is 17 (18) cm higher than the single-leg jump. Also, the jump height is higher even in conditions with external loading, for the same difference of 18 cm.

By comparing the studies described, it can be concluded that the factor way of performance has a significant influence on the increase in the squat jump height, in the first study by 9.8 cm, in the second by 16.9 cm and in the third by 18 cm.

Ergogenic aids

Ergogenic aids are substances such as caffeine, creatine, pharmacological aids, etc. that can improve athletic success, especially by eliminating symptoms of fatigue. Consumption of caffeine stimulates various physiological effects that can contribute to a better performance of maximal intensity exercises. The majority of studies examine the effects of caffeine and its use in endurance sports, while fewer studies examine the effects of caffeine in sports requiring strength and high-intensity activity.

A study by Bloms et al. (Bloms, Fitzgerald, Short & Whitehead, 2016) aimed to examine the effects of caffeine on the performance of vertical jumps (SJ and countermovement jump - CMJ). The participants consumed 5 mg of caffeine/kg of body weight. After 60 minutes, they performed jumps. The results of the study showed that the experimental group achieved a jump height of 34.5 cm from the half-arm, while the placebo group achieved a jump height of 32.8 cm.A significant statistical difference (p = 0.001) was found between the groups using a t-test for dependent samples. However, a study by Blooms et al. (2016) does not provide data on the squat jump height for the examined groups before consuming caffeine.Namely, this is an important data, which could help a more precise determination and more relevant conclusion about the influence of caffeine on the squat jump height.

The results of Blom'set al. study (2016) show that caffeine consumption at a dose of 3 to 5 mg / kg per body weight increases the jump height by 1.7 cm relative to the placebo group.

One of the most tested supplements is creatine monohydrate ($C_4H_9N_3O_2$), which is naturally produced in the liver and kidneys from certain amino acids, and is also used to improve muscle strength and power in athletes. In a study by Stone et al. (Stone, Sanborn, Smith, O'Bryant, Hoke, Utter & Stone, 1999), the effect of creatine monohydrate and calcium pyruvate supplementation on body weight, body composition, and abilities of 42 American football players was examined. One group consumed creatine monohydrate; another group calcium pyruvate; the third group a combination of creatine and calcium pyruvate; fourth was ingesting placebo. Squat jump testing was performed before the start of the study and after five weeks. All participants conducted the same training program during each week. Prior to the start of the program, the first group achieved a jump height of 50 cm; second group 51 cm; third group 50 cm; fourth group 53 cm. Following the training program, the following results were obtained: first group 51 cm; second group 51 cm; third group 50 cm; fourth group 52 cm.Percentage of change for first group is 3.2%; second - 1.3%; third 0.8%; forth 0.4%.In a study by Stone et al. (1999) there was no data on a statistically significant difference between the groups. In this regard, it is not clear to what extent creatine supplementation influence the squat jump height, and no clear conclusions can be drawn about its influence.

In a subsequent study by Ramirez et al. (Ramírez-Campillo, González-Jurado, Martínez, Nakamura, Peñailillo, Meylan & Izquierdo, 2016), the goal was to examine the existence of the effect of creatine monohydrate use along with plyometric training for six weeks on high-intensity and endurance performance in women's soccer. Design of the study defined three groups: plyometric group (placebo), a plyometric group (creatine supplementation) and a control group (placebo) that did not conduct plyometric training. The creatine monohydrate group consumed it at a dose of 20 g per day for the first week, divided into four equal doses, followed by 5 g per day for the next five weeks. The control group and the placebo group received the same doses but glucose. Testing was performed prior to the start of the training program, where the following results were obtained for the squat jump height: control group 23.5 cm; placebo group 25 cm; a group that used creatine 24. 9 cm. After six weeks, testing was again performed, where significant statistical difference was found ($p < 0.05$) between the creatine-using group and placebo group relative to the control group. The percentage change in the group that consumed creatine monohydrate was 8.3%, which indicates a significant statistical difference ($p \leq 0.01$) compared to the initial measurement, also, there is a significant statistical difference ($p<0.05$) compared to the result of the control group of -0.7%after six weeks. The percentage change in the group that consumed the placebo supplement was 5.1%, which is a significant statistical difference ($p \leq 0.05$) compared to the initial measurement. The difference between the arithmetic means was calculated using Cohen's measure of effect which showed a significantly higher effect (ES = 0.47) in the group that consumed creatine monohydrate compared to the group that consumed placebo (ES = 0.27) and the control group (ES = -0.04). This study did not show the measured heights of the squat jump height after six weeks. The authors conclude that the application of the plyometric method of training, but also creatine monohydrate in supplementation, leads to a higher squat jump height in female soccer.

Based on the described studies, it can be concluded that the ergogenic factor in combination with other factors influences in small extent the squat jump height. Due to the lack of certain data, relevant, isolated conclusions cannot be drawn.

INTERNAL FACTORS THAT INFLUENCESQUAT JUMP HEIGHT

Neuromuscular fatigue

There are only a few studies and scientific articles on the effects of neuromuscular fatigue on squat jump. Fatigue in the lower extremities can lead to poor performance of the squat jump due to decreased motor and muscular control. The study by Robineauet al. (Robineau, Jouaux, Lacroix & Babault, 2012) aimed to determine - quantify neuromuscular fatigue of the lower extremities. In order to achieve this goal, they set up a model of a football game lasting 90 minutes, composed of two 45-minute periods, with a rest of 15 minutes. Participants were amateur footballers competing regionally and with experience of more than 10 years of training. The results of the research showed that the squat jump height before the experimental factor was 34.6 cm, at the half time 32.8 cm, then at the end of the match 31.8 cm, which is a significant decrease from the beginning.

Neuromuscular fatigue, expressed by the total duration of the experimental factor, influenced the squat jump height at halftime by reducing it for 1.8 cm and by 2.8 cm at the end compared to the beginning of the match.

In a more recent study by Cooperet al. (Cooper, Dabbs, Davis, Sauls, 2018), the effect of neuromuscular fatigue in the lower extremities on the performance of a squat jump was examined. Recreationally trained participants performed the Bosco protocol, which consists of performing 60s consecutive squatjumps with hands on hips. The study of Cooperet al. (2018) show that the squat jump height before the protocol was 39.48 cm, and after the protocol 35.6 cm. In addition, the maximum speed output before the protocol was 2.41 $m \cdot s^{-1}$, and after the protocol 2.13 $m \cdot s^{-1}$. The rate of velocity development (RVD) before the protocol was 2,162.14 $m \cdot s^{-2}$ and after the protocol 2,408.53$m \cdot s^{-2}$. Bosco's protocol registered significant and acute reduction of the squat jump height, which the authors explain by reducing neuromuscular control and disturbed coordination as a result of fatigue protocol. Cooper et al. (2018) study proved that continuous 60 s of work was sufficient to cause fatigue and to lower squat jump height for 6.8 cm. In this study, data from the Bosco protocol are missing, namely the frequency of jumps and the ground contact time. Both factors are time parameters, determined by neuromuscular coordination, in contrast to the height of the jump, which is a spatial parameter. When planning a training program, it is necessary to determine adequate rests between sets and exercises in order to produce the desired effects on abilities. Keeping a tired player in the game can also increase the risk of injury due to reduced intramuscular and overall coordination and movement efficiency. The goal in every sport is to maintain continuum of optimal efficiency throughout the game.

It can be concluded that in the first study, the fatigue factor have small influence in the negative direction, which reduced squat jump height on half-time and at the end of the compared to the beginning of the modeled match. In another study, in a slightly different way and to a slightly greater influence, the fatigue factor also did the same and reduced the squat jump height after the Bosco protocol.

Growth and sex as internal factors of importance for squat jump height

Growth refers to the increase in the size of the body and its parts, while development refers to the functional changes of the organism (organic systems) that occur during growth. Sports coaches need to understand the physiological characteristics of children because the growth and development of bones, muscles, nerves, and organs largely dictate their physiological capacities and abilities. As children grow, so do functional changes in their organism.In addition to the growth factor, the sex factor is also important for the squat jump height. Observing the biological and physiological aspect of sex factor, certain differences between men and women were noticed, such as the smaller number and size of muscle fibers in women, differences in strength, especially in the upper part of the body, far lower values of the hormone testosterone, etc. (Kenney, Wilmore, Costill, 2015).The squat jump is used as a test to assess neuromuscular abilities and their level of development in children. In a study by Lazaridis et al. (Lazaridis, Bassa, Patikas, Hatzikotoulas, Lazaridis & Kotzamanidis, 2013), biomechanical differences were examined between pre-pubertal volunteer children aged 9 to 11 years and adult men aged 19 to 27 years in performing a squat jump. Participants were untrained and did not participate in systematic sports training for the previous two years. The results of the study showed that the height at all jumps was significantly higher in men. Boys in average achieved a squat jump height of 15 cm, which is far lower than men who achieved a height of 29 cm, a difference of 14 cm. This difference may be due to differences in the variables: vertical force of the substrate reaction (vGRF) and angular acceleration in the knee joint during the concentric phase of the jump, which were significantly higher in adults than in children (p<.001). Also, the electromyographic activity (EMG) of the muscles was lower in kids than adults. EMG was smaller for: m. vastus lateralis, m. tibialis anterior, where EMG was significantly lower (p<0.05) for m. gastrocnemius medialis and m. soleus. In addition, adults showed lower activity of antagonistic muscle groups during the concentric phase of the jump, which may indicate a mismatch of coordination attributes relevant to the performance of jumps. Based on the above, it can be concluded that boys achieve a lower squat jump height compared to adults due to the incompletegrowth process.

In a subsequent study by Nikolaidiset al. (Nikolaidis, Afonso, Clemente-Suarez, Alvarado, Driss, Knechtle & Torres-Luque, 2016), the aim was to examine the relationship between vertical jumps and Wingate anaerobic test in female volleyball. The study involved adolescents aged 16 and adult volleyball players aged 25 years. Adolescents in average achieved a squat jump height of 22 cm, while adult volleyball players achieved 25 cm, a difference of 3 cm. The values of the Wingate anaerobic test variables: absolute strength (P_{peak}) and average strength (P_{mean}) were different for adolescent and adult volleyball players ($p < 0.05$), except for the calculated fatigue index (FI). The squat jump height was found to correlate in low to moderate magnitude with absolute strength (P_{peak}) ($0.28 \leq r \leq 0.46$ in adolescents and $0.58 \leq r \leq 0.61$ in adults) and with average strength (P_{mean}) ($0.43 \leq r \leq 0.51$ in adolescents and $0.67 \leq r \leq 0.71$ in adults) conducted Wingate anaerobic test. Based on the above, it can be concluded that muscle strength plays an important role in meeting the higher height of the semi-squat jump in adult volleyball players compared to adolescent girls.

By comparing the studies described, it can be concluded that the growth factor in the first study, where differences in age are greater than in the second study, highly influences the squat jump height. In another study, the growth factor has little effect on the squat jump height, probably due to the smaller age difference. Also, there is a contingent effect of age and sex factors, which explains the higher jump heights in the first study compared to the second study by 11 cm.

In a subsequent, transversal study by Dore et al. (Doré, Bedu & Van Praagh, 2008), the goal was to examine leg muscle strength and to compare jumping and cycling. The sample consisted of 383 girls and 407 boys ages 9-19. The first test measured the anthropometric values: body mass, body height, length, volume and skinfold measurement on the left leg. Table 3 shows that boys increase the lean leg volume of the leg and the squat jump height up to 17 years, while the lean volume of the leg and the squat jump reach a plateau in girls from 13 to 15 years.

Table 3 Differences of boys and girls in the lean leg volume of the legs and the squat jump height

Age	Sample		Lean leg volume (l)		Squat jump (cm)	
	Girls	Boys	Girls	Boys	Girls	Boys
9-10	34	33	2.36	2.46	21.0	21.6
10-11	39	30	2.91	2.66	22.1	23.2
11-12	39	29	2.96	2.96	22.0	26.1
12-13	45	41	3.86	3.62	25.0	26.0
13-14	27	40	4.35	4.23	24.5	28.6
14-15	19	47	4.42	4.79	25.6	31.3
15-16	54	49	4.72	5.76	26.3	33.5
16-17	59	50	4.77	6.20	24.6	36.2
17-18	43	54	5.01	6.39	25.4	37.9
18-19	24	34	4.70	6.48	25.9	36.8

It can be concluded that boys at all ages achieved higher jump heights than girls, which is explained by the difference in the lean leg volume component of the leg muscles.

There are certain physiological differences between men and women, such as lower numbers and size of muscle fibers in women, differences in strength, especially in the upper body, far lower testosterone hormone levels, etc. These differences determine differences in ability and achievement of sports results.

In a study by Bosco et al. (Bosco, Tsarpela, Foti, Cardinale, Tihanyi, Bonifazi, Viru, Viru, 2002), the characteristics of leg extensor muscles, running speed, and testosterone concentrations were studied, involving 16 male and 12 female sprinters from the Italian national team, ages 22 to 24. They performed squat jump without additional weight and with a weight (a shoulder bar with an external load of 50 to 200% of their BW). The results showed that men performed a significantly higher jump height of 43.1 cm when performing a squat jump without load, compared to 34.4 cm for women, while the difference was smaller when performing a squat jump with an external load 100% of their BW, where men achieved 15.8 cm, and women 13.8 cm. It has been suggested that measured testosterone levels, which were higher in men, had a greater effect on power than women, contributing to a higher jump height. Men are better in explosive power and speed, but not in strength relative to body mass.

It can be concluded that men in conditions without external loading achieve significantly higher jump height than women by 8.7 cm, while in conditions with external loading 100% of their BW, the difference is much smaller and is 2 cm.

Based on the studies described, it can be concluded that, in the study with mature participants, under conditions without external loading, a sex factor moderately influences the increase in the squat jump height. However, when the external load factor is introduced, the squat jump height is greatly reduced (negative direction of the factor). In a study comparing sexduring growth, the higher jump height in boys was contributed by the contingent action of the sex factor and the lean leg volume of the leg. In the comparison of the two studies, it is evident that higher jump heights are achieved due to the contingent effect of the training level of the participants and the growth factor.

CONCLUSION

In this article, factors that influence the squat jump height are analyzed. Based on the analyzed various information sources, primarily scientific papers, conclusions can be drawn about the influence of the observed factors on the squat jump height, which due to the limited insufficient theoretical and practical coverage, do not have a complete deterministic character. In the case of external factors, the way of performance factor has the greatest influence when squat jump is performed with both legs compared to performing on one leg. The smallest influence among external factors is achieved by the ergogenic aids factor (caffeine and creatine monohydrate) in contingent act with the type of training load factor. In the case of internal factors, the greatest influence is achieved by the growth factor, when the age difference is large, while the influence is much smaller when the age difference is less. The smallest influence on the SJ among internal factors is achieved by the neuromuscular fatigue factor, which has a negative direction of action and reduces the squat jump height, in short-term high intensity work.

The type of training load factor, which has smaller influence on the squat jump height than the way of performance factor, may be important in choosing the appropriate type of mechanic load, which can be useful in sports where the duration of training is limited and where there is a tight competition calendar such as team sports. The sex factor showed that men achieved higher jump heights from squat jump, which is explained by the higher value of measured testosterone hormone and the higher fat-free component of the leg.

Holistic knowledge of the external and internal factors which affects squat jump height is necessary for athletes of different profiles, especially scientific researchers and coaches of many sports disciplines (athletics, soccer, basketball, volleyball, swimming, American football, ski jumping, etc.) for more effective and more efficient management of the training process. As methodology and knowledge gained in this field are constantly being improved, it is necessary to constantly monitor their development and thus be current and effective in both research ventures and the training process. In order for research in this field to be more accurate and of greater importance, it is necessary to apply in the research procedure a precise scale of factors influence with clearly formulated criteria and quantitative indicators that determine the levels of influence.

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