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Estimation of explosive power of lower extremities in handball

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Abstract. *Explosive power is one of the most popular motor skills in sports today. It manifests itself as the power of reflection, impact, sudden acceleration, ejection of various devices and props (ball, spear, ball). Sports in which explosive power is significantly represented are: athletic sprints, jumps and throws, parts of sports games, martial arts . We must keep in mind that work on the explosive power of the lower extremities (all types of jumps on one or both legs) can be carried out only under the condition that in the initial period the means of general preparation created the basis for strength and coordination. jumping training. The aim of this paper is to evaluate the explosive power of the lower extremities in handball.*

Key words: *measure, strenght, jump, test*

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Introduction

Modern handball nowadays is reflected in a multitude of fast, explosive and complex movements, fast pace of shifting and development of actions, as well as fast action in the form of situational problem solving. All this together is characterized by a high intensity of activity, which poses a great task for players, and that is to have highly developed motor skills, both basic and specific[2]. Pivač & Marković[34] explain modern handball as a very dynamic game, with a very high level of tempo. A change of place, quick starts, acyclic movements, transfer of the ball, counterattacks, are all characteristics that prevent a handball player from taking a break during a game. Unlike some other sports and sports games, handball equally contains three basic natural forms of movement: running, jumping and throwing. Kuleš & Šimenc[20] investigated the influence of basic motor skills on success in handball and found that explosive power (horizontal and vertical jumps, and throwing type), precision, speed of players with and without the ball, and coordination, define the efficiency of handball players.

All research and considerations lead to the conclusion that modern or contemporary handball can be reflected in the great connection between basic motor skills and direct efficiency in the game itself. Therefore, great attention in the preparation of handball players must be paid to the quality planning, control and monitoring of the condition of the subject, which is certainly related to the expertise of the responsible person. In this regard, Marvić[27] presents the top handball player as a true athlete, who must have the dispositions of a modern athletic decathlon fighter. Precisely for this reason, as mentioned above, great attention must be paid to the physical preparation of handball players, because they are required to suffer great strain. In addition to the above, handball also affects the development of all other abilities and characteristics in the body, such as: functional, constitutional, and especially motor skills. Taking everything into account, it should be noted that Marušić[26] said that the "ideal" of a top handball player, based on model characteristics, without entering into specialization by playing positions, could look like this: tall, relatively large muscle mass, long arms, long fingers, large hands, body muscular, dominated by long leg and arm muscles, strong and accentuated chest, back and abdomen muscles, relative lack of adipose tissue, proportionately built body, high degree of explosive power, fast strong properties and high coordination abilities, high degree aerobic endurance, pronounced perceptual ability, brave, determined, above-average intelligent, imaginative and stable nervous system.

As in any sport, so in handball, the higher the level of competition, handball clubs and players are faced with numerous tasks that must be performed at the highest possible level. Among them are specific technical-tactical components such as: defensive tasks, feints, shots on goal. All these elements directly affect the prevention of the opponent in his intention.

What should be especially emphasized is that the ball control technique must be at an extremely high level because it directly and largely affects the final outcome. Research and notational analysis of international games clearly indicate that handball players perform a large number of high-intensity actions during the match[6]. Such actions are characterized by accelerations and decelerations in different directions (including contact), jumps and slips. All such movements require explosive muscular actions and can be repeated more than 100 times during one game. Increased height of the jump from one leg is a great advantage for one player, because it allows a shot from a higher height, the ability to avoid blocking the opposing player and the player has more time to spend in the air, which is a great opportunity to deceive the goalkeeper[26]. Training

should therefore be aimed at improving vertical reflection in handball players, butthey must consider injury prevention exercises. Kuleš & Šimenc[20] also investigated the influence of basic motor skills on handball success and found that explosive power (horizontal and vertical jumps, and throwing type), precision, speed of movement of players with and without the ball and coordination define the efficiency of handball players[26]. Vuleta, Milanović, Gruić, Jukić, & Pašić[50] determined that Modern handball requires good physical endurance from players, and at the same time it is very important to develop speed and explosive strength and endurance of force.

The ability to jump vertically is crucial to success in handball. Jumping is used during the jump, jump attack from the line of attack, blocking and defending the opponent. A successful player must not only jump high, he must also be able to reach that height quickly. This requires the ability to produce energy in a very short time[49].The use of power during play is determined by the fact that the use of maximum power lasts from 0.5 to 0.7 seconds; however, most explosive moments take significantly less time. For that reason, the optimal use and transformation of the acquired maximum muscle strength into the "explosiveness" of the main muscle group of the lower extremities, which participate in the take-off, requires special strength training[6]. Explosive power expressed through explosive jumps is defined as the ability of the subject's nervous and muscular system to exert muscle tension in the shortest time interval[53]. Vertical jumps and jumps are often used to increase the explosive power of the lower extremities[9]. Jumping is a specific example of the application of muscle strength in eccentrically concentric conditions that occur in different cyclic, acyclic and combined-motor situations. The Myotest wireless accelerometer automatically processes and analyzes the data of the mean values of the tested variables. The transferred data are transferred to a computer and analyzed via Myotest Pro-Software[18].

Anthropological status of man

The anthropological approach is characterized by the recognition of a certain number of human characteristics and abilities on the basis of which each individual human being can be characterized[41]. Man possesses various abilities and qualities. Development and the level reached, as well as their interrelationship, vary from person to person. Anthropological features are organized systems of all characteristics, abilities and motor information and their mutual relations[37]. Anthropological status is a group of anthropological characteristics. One of the more important components of anthropological status is motor ability.

Motor skills

Motor abilities are part of anthropological characteristics, and are based on the specific level of development of the basic latent motor dimensions of man and the ability to participate in solving and performing motor tasks. They allow for successful movement regardless of whether they were acquired through training or not. Many researches of the motor segment of the anthropological status of man have established that motor abilities cannot be characterized by only one dimension (factor), but that it is a multidimensional approach. Each individual motor ability is regulated by

the appropriate mechanisms of the central nervous system that control it, and are related to other human abilities[34].

One of the factors of all human movements and movements is motor ability (anthropomotor, biomotor or psychomotor). They are defined as complex characteristics that are manifested in movement regardless of whether those characteristics are innate or acquired. To a greater or lesser degree, they are genetically predisposed. The training process has a greater impact on motor abilities that are genetically less conditioned[46].

Motor abilities are abilities that participate in solving motor tasks and are responsible for the efficiency of our movement. The hierarchical structure of the motor space is the result of numerous previous studies conducted on different samples of respondents[38]. The study of motor abilities confirmed that this segment is not described with one or several latent dimensions, but it is a complex structure of quantitative (strength, speed, endurance) and qualitative (coordination, flexibility, precision) properties[29].

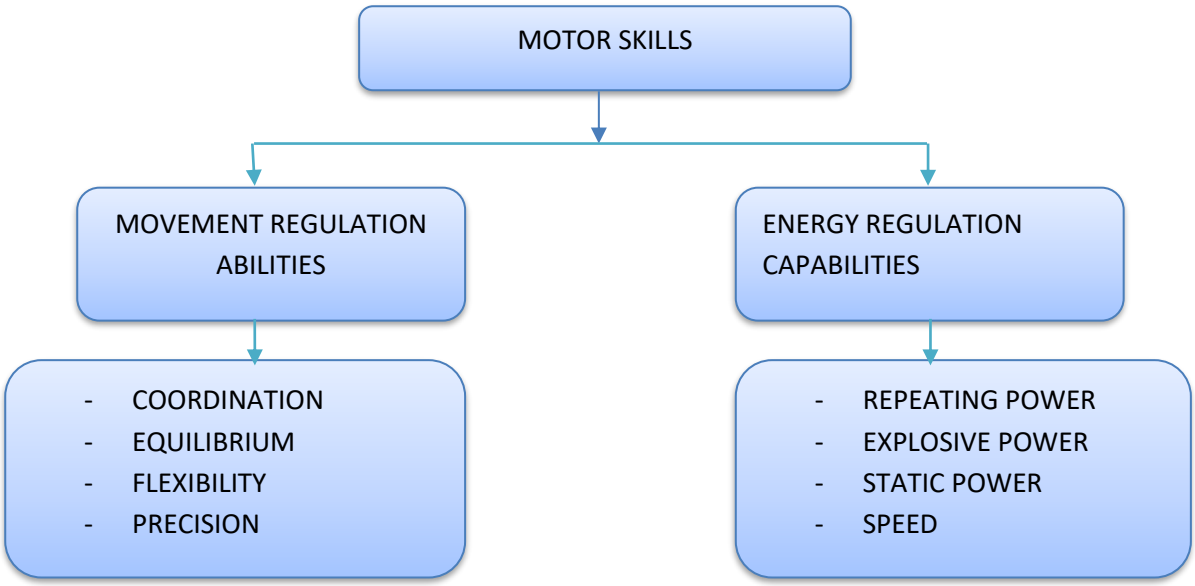

Figure 1: *Hierarchical structure of motor space. Source: Pistotnik. (2003) Fundamentals of Movement.*

Motor abilities are expressed by conducting moving structures in relation to physical parameters (space, time, force). Motor abilities are measurable and are influenced by all physiological and anatomical factors [genetic potential, level of motor information (knowledge), morphological characteristics, energy potential, cognitive abilities, conative characteristics]. Given their complexity, the most difficult task is to determine how to effectively develop the above skills. Studies of motor skills have confirmed that this segment cannot be described by one or several latent dimensions.

Motor skills are a delicate area and are crucial to athletic success. A common feature of motor skills is that they are responsible for solving motor tasks. At their core lies the efficiency of movement.

These abilities enable strong, fast and long-lasting functioning of organic systems, especially the neuromuscular system, which is responsible for the intensity, duration and regulation, as well as precise and coordinated performance of various motor tasks. According to previous research, motor abilities can be divided into a number of groups, each of which can be defined and operationalized.

Motor skills are important not only for oneself, but also for the development of other traits and abilities. If motor skills do not develop to a level that is objectively achievable given the genetic limit, it is likely that such an individual will not be able to perform various daily tasks effectively and easily, nor will the development of other motor traits and abilities be encouraged. related abilities.

In addition, these motor abilities do not have the same innate coefficients, which is why some are less during life, and some more under the influence of the exercise process. Speed, coordination and explosive power are much more innate than repetitive and static power, and even flexibility[23].

Motor skills are one of the basic areas of interest in kinesiology. In particular, in addition to the transformations of aerobic and anaerobic endurance, and the transformation of variable morphological dimensions, motor abilities are the basis of kinesiological action. To this should be added the fact that motor skills are rarely practiced in other scientific fields except in kinesiology. While aerobic abilities are also practiced in the field of medicine, and variable morphological dimensions are also interesting in other scientific fields, motor abilities are very often the focus of interest in kinesiology[13].

Motor abilities are traits that participate in solving motor tasks. Motor ability is the ability to correctly and effectively perform movements, movements or willingly maintain the desired position under the influence of some external forces and factors.

Motor abilities are variable, because they depend on biochemical and morphological changes in the organism. Which means that we influence the development of motor skills through exercise (sports, recreation, etc.) [37].

Motor skills:

- Power (explosive, repetitive and static)
- Speed
- Flexibility
- Coordination
- Precision
- Balance
- Agility

Measurement and testing of motor skills

Measurements in kinesiology can generally be divided into two major groups: laboratory measurements and field measurements.

Laboratory measurements in kinesiology include measurements and laboratory procedures used in the analysis of morphological characteristics of exercisers, biomechanical performance characteristics, various forms of functional diagnostics, and various forms of motor diagnostics. Laboratory measurements are generally accurate and reliable, but at the same time demanding and at very high cost.

The data obtained by laboratory measurements can be considered very accurate, because under the condition of quality implementation, measurements and tests very precisely distinguish the subjects who were measured. This does not only mean that on the basis of these measurements, precise data on "who is better and who is worse" are obtained, but also information on how much is better and who is worse than someone else who was measured on the same test ". Laboratory measurements are also characterized by high reliability. This means that the measurement error is very small, and that the respondents, if they repeat the test one or more times on the same test procedure, will achieve results that will correspond to those achieved for the first time[11].

Field measurements (field tests) in kinesiology - Field measurements (field tests) include test procedures that may include motor diagnostics, tests that can assess aerobic and anaerobic endurance in field conditions, tests that can assess the state of motor knowledge, and to some extent biomechanical analysis of certain motor performances[42].

Field measurements generally have exactly the opposite advantages, but also exactly the opposite disadvantages of laboratory measurements. Field measurements are regularly questionably accurate and reliable, but at the same time very applicable and inexpensive. Why questionably correct? This term "questionable" is intended to emphasize the fact that the same field testing can be "precise" but also "imprecise". Thus, the same field test is "accurate" in one situation and "imprecise" in another because field test procedures can have very high accuracy, but only under conditions of high training of the meter. Same thing with reliability. Measurement errors can occur frequently in field test procedures, but are directly related to inadequate application of the test and / or insufficient training of surveyors[12].

In the system of sports preparation, measurements should be carried out, ie testing of all important dimensions of athlete preparation so that they are expressed as much as possible in numerical values. It is a diagnosis of the current anthropological status of athletes, ie the state of training as well as the effects of training, which is carried out according to certain methodological rules in laboratories and in the field[45].

Such measurements are usually called "motor measurements", ie "motor tests". Motor testing is the systematic use of appropriate tests to quantify motor behavior, ability, and skill in order to predict the motor performance of subjects. Kinesiometry, which is a set of procedures for motor measurements[52], deals with the problems of measuring various forms of motor activities, most often motor abilities and skills.

Motor diagnostics provides valuable data on the level and character of the development of basic and specific motor abilities, to which the training process is directly directed[43].

Basic motor skills imply the presence of those motor abilities that every person has, and specific ones that are the result of a relatively longer engagement in some kinesiological activities. Therefore, tests to assess motor skills can be generally divided into two groups:

- for procbasic motor skills
- for procspecific motor skills

When we talk about motor measurements, then we mean various forms of real measurement based on motor tests, but also various forms of assessment, evaluation, and performance of simple or complex kinesiological activities. In addition, measurements include assessments of the presence, intensity, as well as the utilitarianism of some abilities or characteristics in kinesiological activities, but also such activities in a closer or wider social environment. All this is achieved by various measuring instruments, both motor and psychological, sociological, etc.

Motor tests to assess motor skills can generally be divided into two groups:

- simulated tests
- laboratory tests

Simulated tests are standardized motor tasks that represent fragments from a broader motor (eg sports) activity, or that simulate certain requirements of a motor activity, or that simulate the corresponding real effort of the appropriate group of muscles, or cardio-respiratory system or central nervous system. They are most often performed indoors, or on sports fields, with the use of sports equipment for exercise, or without any equipment[55].

Sensitive period for the development of explosive power

The sensitive period represents the phase of a young athlete in which a special type of training can influence the development of his motor skills. If a professional adheres to strictly prescribed training rules, high results can be achieved, which is to raise the level of motor skills close to the maximum. Since motor abilities are partly conditioned by genetics, progress also depends on the individual directly. Timely reaction and properly planned training can lead to laying a good foundation for further development of the athlete, which could ultimately lead to the final goal, which is to achieve a top result. The question is when development can be most influenced, and when could motor skills develop to a maximum[30]? It is clear that the maximum development of an ability will be reached only when all the natural processes of the organism, while thinking about growth and development, are completed. In addition, it is important that all characteristics related to morphology and motor skills are sufficiently developed. However, in the period of growth and development, there are phases that can be said to be sensitive (sensitive) periods during which we can most develop the capacity for maximum development of a certain motor ability. They are determined according to the stages of biological growth and development and natural trends in the development of the motor system. Then training stimulates and increases natural trends. However, in the period of growth and development, there are phases that can be said to be sensitive (sensitive) periods during which we can most develop the capacity for maximum development of a certain motor ability. They are determined according to the stages of biological growth and development and natural trends in the development of the motor system. Then training stimulates and increases

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The sensitive period or "critical period" for the development of explosive power begins around the age of eight. A large number of researches have come to the results that they are listed as critical phases in the period from the seventh to the seventeenth year, and that the age from 14 to 15 should be singled out. It should be noted that the development of motor skills, like all other processes in the body, does not proceed evenly, but in certain stages. A large number of studies published in German and Soviet literature cite the period from 12, 13 to 18 as a sensitive period. However, some authors believe that in addition to this period, this ability develops earlier, and the critical phases are in the ages of 8 to 9, from 10 to 11, from 13 to 16 and especially from 16 to 17 years of age18.

Table 1. *Sensitive periods for the development of motor skills (Bijelić & Simović, 2005)*

Motor skills	Age														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Balance					*	**	**	*							
Agility			*	*	*	**	**			**	**	**	**	**	
Coordination			*	*	*	*	**	**		*	*	*	*	*	
Speed		*	**	**	**	**	**	**	**	*	*	*			
Power					*	*	*	**	**	**	**	**	**	**	**
Flexibility				*	**	**	**	*	*						
Endurance	*	*	*	*	*	*	*	**	**	**	**	**	**	**	**

**** Note: ** -*** *sensitive period of development, ** - the most suitable sensitive period of development*

Further research can lead to more precise explanations of the sensitive phases concerning special types of explosive power. Thus, Malina, Bouchard, & Bar-Or[25] believe that the explosive power of the horizontal and vertical jump type can be directly influenced up to the age of 18. On the other hand, Issurin[19] believes that the same motor ability can be most affected by training from 13 to 17 years of age. If all these facts are realized, and at the same time it does not deviate from the correct work, we can start with the application of specific training loads that have a positive effect on the

development of explosive power. Some of these methods are certainly plyometrics and Olympic weightlifting.

If we look back at the research and findings so far, we can notice that the explosive power is of the general type. This means that an athlete who has great explosive power of the arms will also have great explosive power of the legs, ie. any muscle group. We can freely say that the upper limit for the development of explosive power as a motor ability is around the age of 20 to 22, and its decline begins to occur after the age of 30.

Measuring instruments for estimating the explosive power of the lower extremities

Modern diagnostic equipment (eg contact mats, force measuring platforms, kinematic systems, etc.) allowsexact monitoring of a number of parameters by which it is possible to estimate the components of explosive power1. Some of the parameters that estimate the level of explosive power are: maximum dynamic force of force (RFD - rate of force development), maximum (Pmax) or average mechanical force generated during the concentric (propulsive) phase of movement, jump height (h), etc.

This paper will present some of the tests for measuring explosive power of the vertical jump type, and these are tests in which vertical jumps are performed with or without load on the force measuring platform.

Kistler's tensiometric platforms have been the standard in biomechanics and sports science around the world for twenty-five years. Quattro Jump consists of a movable tensiometric platform on which different types of jumps are performed, and its dimensions are 920x920x125 mm. The subject of testing on the platform are different types of vertical jumps. The performance of the jumps is analyzed by a computer connected to the Quattro Jump system protocol. In cooperation with others. With Carmel Bosco, Kistler developed the Quattro Jump Bosco Protocol, a special protocol that allows quantification of performance related to lower extremity activity, which allows objective measurement of force and time and calculation of other previously mentioned quantities: strength, jump height, number of jumps and more[5].

Basic information related to testing

Unlike other methods for estimating vertical jump parameters, Quattro Jump measures precisely that segment that is of significant interest - the force of the jump in relation to time. The end result and its specificity conditions the variety of parameters and is presented within the specific jump protocol.

Vertical jump explosive power tests must be specific, ie. in the function of the sports branch and its application in it. It is important when choosing tests that tests are not used because either apparatus or professional guidance has been used before, or because at the time of testing we have the ability to use the equipment. Jumps in the function of testing the explosive power of the vertical jump type can be performed one-legged or one-legged. One-legged jumps are performed once so that one leg is isolated during the jump to obtain informationabout the components of each lower extremity separately.

Sun jumps are applied as single or multiple jumps. One-time jumps provide information on the concentric and eccentric-concentric components of the explosiveness of a vertical jump.

Multiple jumps are performed with a smaller or larger amplitude in the knee joint, and the interpretation indicates the degree of elastic explosive power, maximum anaerobic strength or strong endurance in performing explosive activities. One-time tests of explosive power of the vertical jump type are repeated in at least three particles, while tests of multiple character are performed as one particle - the result and correct execution techniques.

Tests to estimate the explosive power of the jump type

Laboratory tests to assess jumping

The purpose of the tests is to estimate the explosive power of the vertical jump type. They are performed in laboratory conditions on a tensometric platform according to a special protocol (Quatro Jump Bosco Test), which enables objective measurement: jump forces in relation to time, manifested force, jump height and reaction time. The Bosco test protocol consists of:

- ***Squat Jump-SJ*** [43]

  It is derived from a static position. The subject's hands are fixed on the hips (due to maximum isolation during the jump), he stands in an upright position for a few seconds from which he descends to a semi-squat position (legs are flexed at the knees at an angle of 90º) where he rests for two seconds. The resting phase is followed by a maximum vertical jump, and a landing with slight flexion in the knees. This is followed by re-taking the starting position. The test assesses the concentric component of the jump explosiveness (jump height measured in centimeters).

Figure 2. I *Squat Jump (SJ)*

- Counter Movement Jump CMJ [43]

During the test, all phases of the jump are connected, ie. there is no pause at the moment of changing direction. The subject's hands are fixed on the hips (due to maximum isolation during the jump). He stands in an upright position for a few seconds from which he descends into a semi-squat position (legs are flexed at the knees at an angle of 90º) and without stopping at the point of

change of direction of movement, performs the maximum vertical jump. This is followed by a soft landing with slight flexion in the knees. This is followed by taking up the starting position again. The test evaluates the eccentric-concentric component of the jump explosiveness (jump height measured in centimeters).

Figure 3. *Performing a squat jump with preparation in stages (Counter Movement Jump-CMJ)*

- One-legged Counter Movement Jump (CMJ L / D)[43]

Derived from a static position on one leg. The subject's hands are fixed on the hips (due to maximum isolation during the jump). The leg with which the jump is performed is flexed in the knee at an angle of 90º, and the insulated leg is placed in the position that the lower leg is raised from the ground (with the knee in line with the knee of the leg with which the jump is performed). He stands in an upright position for a few seconds from which he descends to the half-squat position and without stopping at the point of changing the direction of movement, performs the maximum vertical jump on one leg. The landing is on the same leg with slight flexion in the knee. This is followed by re-taking the initial foot position. The test evaluates the concentric component of the explosiveness of a one-legged jump (the height of the jump measured in centimeters).

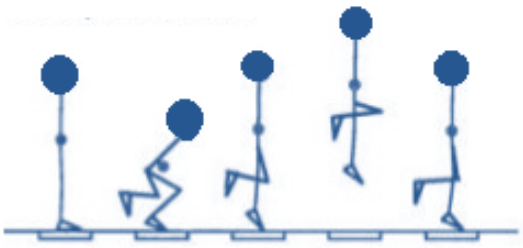

Figure 4. *One-legged Counter Movement Jump-CMJ-phase jump display*

- ***Maximal Counter Movement Jump-CMJmax***[43]

  It is performed identically as a squat jump with preparation. The difference is that the arms are not isolated on the hips, but are in the function of swing (in order to achieve the maximum jump height). In the initial position, the arms are in the chest height. Coordinated with the squat, the respondent performs the engagement, followed by the maximum reflection and swing of the hands through the phase of pre-stretching to caressing.

Movement is characteristic of most situations that occur during sports activities. Coordinated swing of the arms as a function of the jump contributes to a higher jump height by 10% [17]. The test evaluates the eccentric-concentric component of the jump explosiveness (jump height measured in centimeters) and limb coordination in performing the jump.

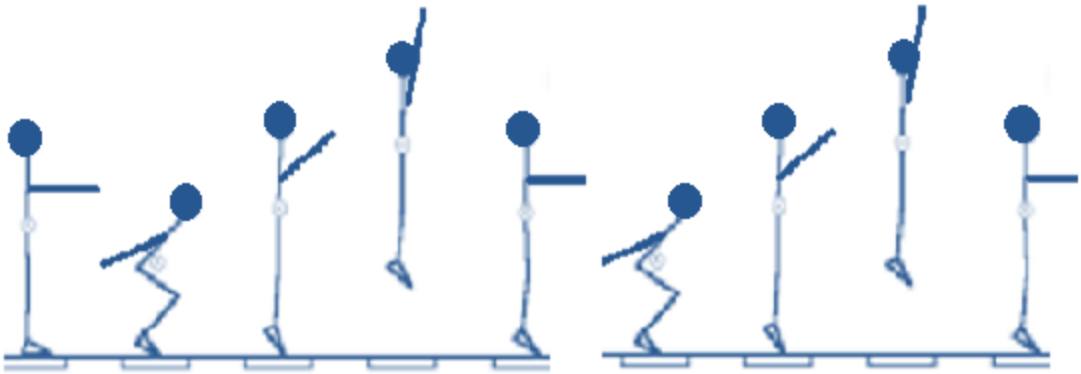

Figure 5. *Maximal Counter Movement Jump-CMJmax-phase jump display*

- ***Multiple Continuous Jump with Bent Legs-CJb for 15 to 60 seconds*** [43]

The test requirements are the jump height and the jump frequency in a given time interval. The subject's hands are fixed on the hips (due to maximum isolation during the jump). The subject stands in an upright position for a few seconds, and after the sound signal begins to perform continuous squat jumps with preparation. During the contact phase with the ground (landing phase), the legs must be flexed at the knees at an angle of approximately 90º. Depending on the duration, the test estimates: maximum anaerobic strength (15s and strong endurance in performing explosive activities) (45 or 60s) Values are expressed in the form of the height of the measured jump (cm) or as the average mechanical strength (W / kg). used in sports where there is a need for continuous explosive reflections (speed skating, skiing).

Figure 6. *Perform Continuous Jump with Bent Legs-CJb*

- ***Multiple Continuous Jump with Straight Legs-CJs*** [43]

CJs is a test to assess the reactive explosive power of the muscles of the back of the lower leg and the muscles of the foot. He found his justification in sports (triple jump, high jump) which require strength and great tolerance of the elastic energy of the tendon apparatus. The test consists of performing a series of six to seven jumps, isolating and analyzing the five best technically and

results-wise. The subject's hands are fixed on the hips (due to maximum isolation during the jump). He stands in an upright position for a few seconds and then continuously starts performing jumps. Make sure that the legs are extended at the knee joint in the phase of contact with the ground (jumps are performed from the ankle). The values are expressed in the form of the height of the measured jump (cm) or as a reactive index (duration of the flight phase and contact with the ground).

Figure 7.*Multiple jumps with straight legs (CJs) - a representation of the jump in stages.*

Field tests to assess jumping

- ***Vertical jump with arm swing***[43], test to assess the explosive power of the lower extremities. The task of the examinee is to perform the maximum reflection and touch as much as possible the placed measuring sheet (Vertec measuring system) or leave a fingerprint on the measuring scale on the wall (Sargent). It is necessary to perform two correct vertical jumps. The rest between jumps is 30 s. The height of the reach recorded in the standing position is deducted from the measured reach height in the jump. The obtained result in centimeters (cm) represents the jump height of the examinees.

Figure 8. *Demonstration of performing a vertical jump using the Vertec system*

- ***Long jump from place (*Standing broad jump)[43]**

Test to estimate the explosive power of the jump type. Equipment and props required to perform the test: Non-slip surface, if possible two judo mats (or similar), placed longitudinally and level, marking chalk, centimeter measuring tape.

Instructions for respondents: In a hip-width apart position, with feet placed behind the marked line, the subject flexes the knees slightly and extends the arms forward parallel to the ground. When he swings his arms, he reflects as hard as he can and jumps as far as possible. He tries to land on his feet and stay upright. The test is performed twice and a better result is recorded.

Instructions for meters: On a landing mat, draw lines every 10 cm, starting 1 m from the starting line. Place the measuring tape (meter) upright on the starting line, so that it gives the correct measure (0 cm at the beginning in the starting line). Stand to the side and record the length of the jump. The length is measured from the front edge of the starting line to the point where the back of the heel (closest to the bounce line) landed on the mat. If the subject falls backwards or touches the mat with any part of the body, he is allowed an additional attempt. The springboard and landing mat must be level and firmly attached to the floor.

Test score: The better score from two attempts is a score. It is expressed in centimeters. Example: A result of 1m and 56 cm.

Figure 9. *Standing broad jump*

- ***Cost from the place (*Triple hop test)[24]**

The task is performed in a space of minimum dimensions 15x3 meters. One shorter side of the space leans against the wall. A mat is placed next to the wall at the narrower end, and in its extension the other four. The wall is used to fix the mat. The mats are 2 meters long, so the total length of the space covered by the mats is 10 meters. The length of the entire trail is 15 meters.

The scale for measuring the length of the jump starts on the side opposite the wall. From the fourth meter until the end of the trail, parallel lines of 20 cm in length were drawn on each side of the mat. Full meters, decimeters and every 5 centimeters are specially marked. The subject stands with his feet behind the reflection line. It bounces first on the foot, lands on one foot, then on the other, and finally lands foot on the mat.

The result of the examinee is the length of the correct jump from the reflection line to the back of the heel footprint which is closer to the place of reflection. The respondent jumps three times in a row, and the best jump is registered.

Figure 10. *Triple hop test -Triple jump from the place*

Measuring instruments for estimating the specific explosive power of the jumping type in handball

When testing the explosive power of the lower extremities in handball, we must use specific measuring instruments, which are adapted to the game of handball. The explosive power of the lower extremities is mostly manifested when performing feints and performing counter-attacks and during actions on the opponent's goal. Certainly, experience and better preparation technique contribute to simpler and better mastering of tasks, so that respondents with a longer training period will achieve better results.

Tests to assess the specific explosive power of the lower extremities in handball are performed in field and laboratory conditions, and below we will single out some of them:

1. ***Vertical jump with one leg*** (Vertical Countermovement Jump),
2. ***Horizontal jump with one leg*** (Horizontal Countermovement Jump),
3. ***Lateral CMJ*** (Lateral Countermovement Jump).

1. Vertical jump with one leg -Vertical Countermovement Jump[28]

Test description: The respondent is in a parallel position. They are instructed to step with the foot of a certain foot on the platform, with their hands on their hips, sink to a self-determined depth as fast as they can and then jump as high as they can in the upcoming concentric phase and land on both feet. The subject's jump is calculated from the moment the foot touches the contact pad system.

Result: The result is calculated by a computer program, where the Fitro Jumpe-Fitronic jumping platform is most commonly used, which is a software-related platform that can be used to obtain the exact jump height by measuring the duration of foot contact with the ground and the flight phase.

2. Horizontal jump with one leg - Horizontal Countermovement Jump[28]

Test description: The subject stands in a standing position, on a certain test leg with his fingers on the starting line and his hands on his hips. The subject is instructed to sink to only a certain depth as soon as he can, and then jump as far forward as he can and land on both feet.

Test result: The test result represents the maximum jump distance of the test with a reflection from one leg (left or right), and is calculatedis approximately 0.01m, with a measuring tape.

3. Lateral CMJ - Lateral Countermovement Jump[28]

Test description: The subject is in a standing position, on one leg, with the foot at the starting line and the hands on the hips. The respondent was instructed to sink to only a certain depth as soon as he could and then to jump sideways (sideways) inwards as far as he could and then to land on both feet. The distance achieved was measured at least 0.01m with a measuring tape.

Test result: The test result represents the maximum jump distance of the test with the reflection of one leg (left or right), to the side and is calculatedis approximately 0.01m, with a measuring tape.

A proposal for a battery of tests to assess the explosive power of handball players

In the previous chapter, the measuring instruments, which were used to estimate the explosive power of the lower extremities in handball, were inspected. Taking into account the necessary props, rooms, which are needed to perform the tests, and the time period, which is needed to perform the tests, measuring instruments, ie. The tests proposed to assess this motor ability are:

1. ***Squat jump (****Squat Jump-SJ)*
2. *Jump away from the place* -Standing broad jump
3. ***Cost from the place***-Triple hop test

Regarding specific tests to assess the explosive power of the lower extremities in handball, the following tests are proposed:

1. **Vertical jump with one leg** (Vertical Countermovement Jump)
2. **Horizontal jump with one leg** (Horizontal Countermovement Jump)
3. ***Lateral SMJ (****Lateral Countermovement Jump)*

Conclusion

Explosive power of the horizontal and vertical jump type can be directly affected up to the age of 18. On the other hand, Issurin (2008) believes that the same motor ability can be most affected by training from 13 to 17 years of age. If all these facts are realized, and at the same time it does not deviate from the correct work, we can start with the application of specific training loads that have a positive effect on the development of explosive power. Some of these methods are certainly plyometrics and Olympic weightlifting. If we look back at the research and findings so far, we can notice that the explosive power is of the general type. This means that an athlete who has great explosive power of the arms will also have great explosive power of the legs, ie. any muscle group. We can freely say that the upper limit for the development of explosive power as a motor ability is around the age of 20 to 22,

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References

1. *Antekolovic, Lj. (1999). Ergo-jump - a simple procedure for testing jumping. In Ž. Hraski & BR Matković (Ed.), Proceedings of the 8th Zagreb Sports Fair "Coach and Modern Diagnostics", (pp. 51-56). Zagreb, HR: Faculty of Physical Education, University of Zagreb.*
2. *Bulava, B., Rodić, S., & Gruić, I. (2011). Influence of basic and specific motor abilities on shooting accuracy in handball. In I. Prskalo and D. Novak (Eds.), Proceedings of the 6th Congress of FIEP Europe "Physical and Health Culture in the 21st Century-Student Competences", (pp. 558-563). 18-21. June, 2011. Poreč, HR: Croatian Kinesiology Association.*
3. *Bijelić, S., & Simović, S. (2005). Training technology in working with young athletes. Banja Luka, Republika Srpska: Secretariat for Sports and Youth in the Government of Republika Srpska.*
4. *Bulava, B., Rodić, S., & Gruić, I. (2011). Influence of basic and specific motor abilities on shooting accuracy in handball. In I. Prskalo and D. Novak (Eds.), Proceedings of the 6th Congress of FIEP Europe "Physical and Health Culture in the 21st Century-Student Competences", (pp. 558-563). 18-21. June, 2011. Poreč, HR: Croatian Kinesiology Association.*
5. *Bosco, C. (1997). A new training method whit Ergopower- Bosco System. ActaAcademia Olimpiquae Estoniae, 5, 24-34.*
6. *Chelly, MS., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., & Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump- and sprint performances in junior soccer players. Journal Strength Conditioning Research, 23: 2241–2249.*
7. *Chelly, MS., Hermassi, S., Aouadi, R., Khalifa, R., Van den Tillaar, R., Chamari, K. (2011). Match analysis of elite adolescent team handball players. Journal Strength Conditioning Research, 25:2410-2417.*
8. *Čanaki, M., Šoš, K., & Vučetić, V. (2006). Diagnosis of explosive power of vertical jump type on the Quattro jump force measurement platform. Fitness Training, 4 (1), 19-24.*
9. *Ebben, WP (2005). Practical guidelines for plymetric intensity. NSCA's Performance Training Journal, 6 (5), 12-16.*
10. *Erkmen, N., Tashkin, H., Sanioğlu, A., Kaplan, T., & Baştürk, D. (2010). Relationshipsbetween balance and functional performance in football players. Journal of HumanKinetics, 26, 21-29.*
11. *Fenstermaker, KL, Plowman, SA, & Looney, MA (1992). Validation of the Rockport Fitness Walking Test in females 65 years and older. Research Quarterly for Exercise and Sport, 63 (3), 322-327.*
12. *Fernandez-Fernandez, J., de la Aleja Tellez, JG, Moya-Ramon, M., CabelloManrique, D., & Mendez-Villanueva, A. (2013). Gender differences in game217responses during badminton match play. Journal Strength Conditioning Research, 27.*
13. *Figueira, FR, Umpierre, D., Cureau, FV, Zucatti, AT, Dalzochio, MB, Leitao, CB, & Schaan, BD (2014). Association between physical activity advice only or structured exercise training with blood pressure levels in patients with type 2 diabetes: a systematic review and meta-analysis. International Journal of Sports Medicine, 44 (11), 1557-1572.*
14. *Findak, V. & Prskalo, I., (2004). Kinesiological lexicon for teachers. Petrinja, HR: Teacher Training College in Petrinja.*
15. *Gabrijelić, M. (1977). Manifest and latent dimensions of top athletes of some team sports games in motor, cognitive and conative space. (doctoraldissertation), Zagreb, HR: Faculty of Physical Education in Zagreb.*
16. *Gambetta, V., & Clark, M. (1998). A formula for function. Training andConditioning, 8 (4), 24-29.*
17. *Harman, EA, Rosenstein, MT, Frykman, PN, & Rosenstain, RM (1990). The effect of arms and countermovement on vertical jumping. Medicine and Science in Sports and Exercise, 22 (6), 825-833.*

18. *Ignjatović, A., Stanković, R., Radovanović, D., & Purenović, T. (2009). Standards and differences in vertical jump assessment. In N. Živanović (Ed.), 5th FIEPEuropean Congress and 2nd Serbian Congress of PE Teachers, (pp. 144-149). September, 23-26, 2009, Nis, RS: Facultz of Sport and Physical Education of Universitz of Nis.*
19. *Issurin, UK (2008). Block Periodization 2: fundamental concepts and training design. Michigan: Ultimate Athlete Concepts.*
20. *Kuleš, B., & Šimenc, Z. (1983). Relationship between basic motor skills and performance in handball. Kinesiology 2, 153-163.*
21. *Krüger, K., Pilat, C., Ueckert, K., Frech, T. &, Mooren, FC. (2013). Physical performance profile of handball players is related to playing position and playing class. Journal of Strength Conditioning Research, 28: 117-125.*
22. *Laffaye, G., Bardy, BG., Durey, A. (2005). Leg stiffness and expertise in men jumping. International Journal of Sports and Exercise Medicine, 37: 536-543.*
23. *Lončar, L. (2011). Motor abilities of children from 7 to 10 years (graduate thesis). Zagreb, HR: Učiteljski fakultet, Odsjek za učiteljske studije Zagreb.*
24. *Madić, D., Nikolić, M., & Stojiljković, D. (2015). Measuring instruments in sports, physical education and recreation. Nis, RS: Faculty of Sports and Physical Education, University of Nis.*
25. *Raspberry, RM, Bouchard, C., & Bar-Or, O. (2004). Growth, maturation and physical activity (2nd edition). Champaign, IL: Human Kinetics.*
26. *Marušić, R. (2007). Handball - step by step. Nikšić, CG: Faculty of Philosophy, University of Montenegro*
27. *Mavrić, F. (2006). Streatching program for handball training needs. Sport Mont 4 (10-11), 216-222.*
28. *Meylan, CMP, Nosaka, K., Green, J., Cronin, JB (2010). Temporal and kinetic analysis of unilateral jumping in the vertical, horizontal, and lateral directions. Journal of Sports Sciences, 545-554.*
29. *Milanović, D. (2004). Training theory: a manual for monitoring teaching and exam preparation. Zagreb, HR: Faculty of Kinesiology, University of Zagreb.*
30. *Milanović, D., Gregov, C., & Šalaj, S. (2010). Periodization of speed-explosive abilities. In I. Jukić, C. Gregov, S. Šalaj, L. Milanović, & T. Trošt-Bobić, (Eds.). Proceedings of the 8th International Scientific Conference "Fitness Training of Athletes - Training of speed, agility and explosiveness", (pp. 60-67). February, 26-27, 2010, Zagreb, HR: Faculty of Kinesiology, University of Zagreb.*
31. *Milanović, D. (2010). Training theory and methodology. Zagreb, HR: Faculty of Kinesiology, University of Zagreb.*
32. *Pejčić, A. (2005). Kinesiological activities for preschool and early school age children. Rijeka, HR: Teacher Training College in Rijeka.*
33. *Peirson, L., Fitzpatrick-Lewis, D., Morrison, K., Warren, R., Usman Ali, M., & Raina, P. (2015). Treatment of overweight and obesity in children and youth: asystematic review and meta-analysis. CMAJ Open, 3 (1), E35-46.*
34. *Pivač, N. & Marković, S. (2005). Basic principles and the relationship between basic and specific physical preparation of handball players. Sport Mont, 3 (6-7), 339-348.*
35. *Prskalo, I. (2004). Fundamentals of kinesiology. Petrinja, HR: Teacher Training College Petrinja.*
36. *Pistotnik, B. (2003.) Fundamentals of movement: Motor skills and basic means for their development in sports practice. Ljubljana, SI: Institute of Sports, Faculty of Sports, University of Ljubljana.*
37. *Sekulić, D. & Metikoš, D. (2007). Fundamentals of transformational procedures in kinesiology: an introduction to basic kinesiological transformations. Split, HR: Faculty of Natural Sciences, Mathematics and Kinesiology, University of Zagreb.*
38. *Sekulic, D., Krolo, A., Spasic, M., Uljevic, O., & Peric, M. (2014). Thedevelopment of a new stop'n'go reactive-agility test. Journal of Strength Conditioning Research, 3306-3312.*

39. *Sudarov, N. & Fratrić, F. (2010). Diagnosis of athlete training. Novi Sad, RS: Provincial Institute for Sports.*
40. *Suzović, D., Marković, G., Pašić, M., & Jarić, S. (2013). Optimum load in vertical jumps performed with and without muscle stretch-shortening cycle. International Journal of Sports Medicine.*
41. *Stanev, S. (1981). Tehnieskaja padgotovka ljohko athletes - metatelij. Moscow, RUS: Physical Education and Sports.*
42. *Stojiljkovic, S. (2005). Fitness. Belgrade: Faculty of Sports and Physical Education*
43. *Trunić, N. (2007). Training of young basketball players of different age categories, Belgrade: College of Sports.*
44. *Verhošanski, JV (1979). Strength development in sports. Belgrade: Partizan.*
45. *Vuleta, D. (1997). Kinesiological analysis of technical and tactical contents of handball. (doctoral dissertation), Zagreb: Faculty of Physical Education.*
46. *Vuleta, D., Milanovic, D., Gruic. I., Jukić. I., & Pašić, Z. (2006). Relations betweenindicators of basic motor abilities and results of goal throwing accuracy tests. Bulletin of the South Ural University of Economics. Series education, health care, physical culture, 3, 106-108..*
47. *Wagner H, & Müller E. (2008). The effects of differential and variable training on the quality parameters of a handball throw. Journal of Sports Biomechanics, 7: 54-71.*
48. *Željaskov, C. (2004). Fitness training of top athletes. Belgrade, RS: Sports Academy.*
49. *Šalaj, S. (2011). Bilateral lower extremity strength deficit: influence of fatigue, type and speed of muscle contraction. (doctoral dissertation), Zagreb: Faculty of Kinesiology.*
50. *Šimenc, Z. (1982). Relationship between basic motor skills and performance in handball. Kinesiology, 2, 153-163.*
51. *Šoše, H. & Rađo, I. (1998). Measurement in kinesiology. Sarajevo: Faculty of Physical Education.*
52. *Koprivica, V. (2002). Basics of sports training. Belgrade, RS: Faculty of Sports and Physical Education.*
53. *Verhošanski, JI (1979). Strength development in sports. Belgrade strength in sports. Belgrade, RS: NIP Partizan.*

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