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INFLUENCE OF BIOMECHANICAL PROPERTIES OF PARTICULAR SKELETAL MUSCLES ON CHILD MOTOR DEVELOPEMENT

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ABSTRACT

Motor activity in childhood is extremely important for general development of a child, yet there is still not enough information about the children's motor development. Already in the structure of the motor space of the child itself, especially in the mechanisms that govern the movement, it is possible to perceive peculiarities that cannot be ignored when choosing the appropriate way of working with the child. The power of argument of kinesiology, however, is based first of all on appropriate, objective and reliable information, since only verified data can be applied in practice as a basis for the development of exercise programs suitable for the child. In this study TMG (tensiomiography), as a non-invasive measuring method for detection of contractile properties of skeletal muscles, has been applied

Key words: tensiomiography, skeletal muscles, electrical stimulation, primary school pupils, atlas of skeletal muscles

INFLUENZA DELLE PROPRIETÀ BIOMECCANICHE DI DETERMINATI MUSCOLI SCHELETRICI SULLO SVILUPPO MOTORIO DEL BAMBINO

SINTESI

Benché durante l'infanzia l'attività motoria sia estremamente importante per lo sviluppo generale dei bambini, non siamo ancora in possesso di informazioni sufficienti riguardo al loro svilluppo motorio. È già nella struttura dello spazio motorio dei bambini, specialmente nei meccanismi che ne governano il movimento, che possiamo percepire peculiarità che non possono venir ignorate durante la scelta del metodo di lavoro più appropriato con i bambini. Comunque, la potenza dell'argomento della cinesiologia è basata prima di tutto su un'informazione appropriata, obiettiva ed attendibile, visto che solamente dati verificati possono venir applicati in pratica, come base per lo sviluppo di programmi d'esercizio adatti ai bambini. In questo studio la TMG (tensiomiografia) è stata applicata come metodo di misura non invasivo per la scoperta delle proprietà contrattili dei muscoli scheletrici.

Parole chiave: tensiomiografia, muscoli scheletrici, stimolazione elettrica, allievi della scuola elementare, atlante dei muscoli scheletrici

INTRODUCTION

The development of a child involves qualitative and quantitative changes that are permanent and are represented by the change in the structure of the psychosomatic status. The quantitative changes are reflected mainly through anatomic and functional changes that occur during the physical growth. In the first two years the growth is extremely rapid, later it gets a little more moderate, but in the age of adolescence it becomes more turbulent again. The changes occurring in the physical growth can be perceived in the proportions among individual parts of the body as well as in their structure.

The development of a child determines the qualitative changes in the psychosomatic status and as such it is based on the maturing of the nervous system, allowing the child to advance to a higher level of functioning. The process of maturation is hereditary, therefore we are not able to interfere with the sequence of abilities and readiness for action. However, providing a child with an experience-rich environment will help him develop certain forms of activities faster and with a stronger intensity.

In the early childhood mainly the rough motor abilities are developed, the fine motor abilities following gradually from the age three on. In the early stages of the motor development the muscular structure is composed mostly by slow muscular fiber, involved in slow – major motor units that allow a child to perform rough and inaccurate movement. A finer correction of the movement is performed by means of minor – rapid motor units. In the further stages of the child's development the muscular fiber become classified into slow, rapid – persistent and fast – wearing. The fastest development of this classification takes place until the age three and continues until the end of the puberty. This development progresses in correlation with the effectiveness of the functioning of individual centres in the central nervous system and the mechanisms that control and coordinate the functioning of the peripheral system. The control of the peripheral system in turn is an outcome of the processes of learning, which coincide with the child's susceptibility and stage of the development of the whole organism. As the child's development as a whole does not always proceed continuously, the processes of acceleration and retardation must be taken into consideration as well when examining it. In addition to lack of movement stimuli, irregular growth, inadequate development of the nervous system, various emotional and social factors or belated intellectual development are the main causes for retarded and unbalanced motor development.

On the basis of physiological, psychological and neurological findings Luria (1976) developed the theory of functional organization of the brain and its systems. He divided the brain in three basic blocks: the block for the regulation of tonus and the state of alertness, the block for the reception, processing and storing information and the block for programming, regulating and control of complex operations. Each human activity demands coordinated functioning of all the three blocks. In each of the three brain blocks there is a hierarchic structure of three zones – from the simplest to the most complicated one. They are: the primary (projection) zone, the secondary (projection-associative) zone and the tertiary (associative) zone. The tertiary zone plays the most important role in the creation of the most demanding forms of activities and makes possible the coordinated work of the cortical analysers, so its function is to integrate the cortex of the cerebrum. These most developed areas of the cortex are the last to mature. The mielinisation ("maturation" of the nervous paths) of the primary zones is accomplished relatively early, while the mielinisation of the secondary and more so of the tertiary zones takes longer – it is accomplished as late as approximately at the age of seven or even later.

Too little motor activity or complete absence of it in education of growing up youth cannot be entirely compensated later on, as with the progress of growth and maturing the influence of motor stimuli weakens. The lack of experience and opportunities to practice motor activities can make the motor as well as the intellectual development of a child slower (Kelly & Kelly, 1985; Humphrey, 1991). In early childhood the child is very susceptible for the impulses from the environment. The influence of motor activities on his development as a whole is most important at this age (until the age five), after that it gradually decreases. For a young child motor activity is of crucial importance as it includes all areas of expression: motor, cognitive, conative, emotional and social. All these areas have (as a means of reinforcement) a very important role in the learning process itself (Gardner, 1995; Kiphard, 1989; Pišot, 2000a, 2000b) as well as in the formation of the child's personality as a whole.

The relation between the motor and cognitive capabilities and their influence in the regulation of movement must be explained through the phenomenon of the development of a child as a whole. In his "multiple intelligence theory" Gardner (1995) discusses the dimensions of human mind and defines (among others) the body- movement intelligence. He explains it as the capability of using one's own body in various skilful ways and a capability of skilfully manipulating objects. Also F. Bartlet (according to Gardner, 1995) emphasis the importance of these connections in motor activities. He claims that the same principle that has been discovered in clearly physical demonstration of motor skills is true also of the majority of processes to which we usually refer to as processes of thinking. The theory on this relation, that is particularly strongly present in a child, is

being reinforced also by the latest findings of neuropsychologists. In his research on how brain hemispheres are activated during motor activities R. Sperry (Gardner, 1995) pointed out that mental activities must be considered as a means that allows us to carry out action. The processes in the brain should therefore be considered as a means of bringing into motor behavior a higher degree of detail, a more intense focusing towards the objective and a higher degree of general adaptability. The development of motor abilities of a child should thus be considered in a broader sense, not only with regard to physical activities in childhood, but taking into account all sorts of cognitive operations (Bruner and Fischer, quoted in Gardner, 1995). Coordinated action of mechanisms for reception, processing and analysis of afferent and reafferent information in the central nervous system, the activity of the inner and of the outer regulation circuit and of the highest cortical structures in both hemispheres is necessary for effective performing of motor structures.

The role of cognitive activity in the regulation of movement has been explicitly pointed out in various research that set to define the phenomenon and functional model of the motor space structure (Mejovšek, 1979; Madič, 1986; Planinšec, 1995; Pišot, 1999). The cognitive activity is crucial to optimal performance of motor tasks and it is particularly important in the performance of apparently simple tasks. These interrelations occur most frequently when a child grows up, due to their developmental peculiarities.

The early childhood is a particular phenomenon in the explanation of the regulation of movement. The research data leads to the formation of a hypothetical model of the structure of a child's motor space, being a great deal different from the adult's motor space (Pišot, 1999). The latter is classified into three dimensions that represent a child's motor space and as motor abilities guarantee his motor efficacy:

- Coordination – different forms of coordination that refer to motor tasks that are a part of informational and energetic component of movement.
- Strength – different forms of strength that represent the energetic support in the performance of certain relatively simple motor tasks.
- Balance – represents a kind of a filter in the regulation of movement, the presence or absence of which enables and stimulates or prevents and hinders the performance of complex as well as apparently simple motor tasks.

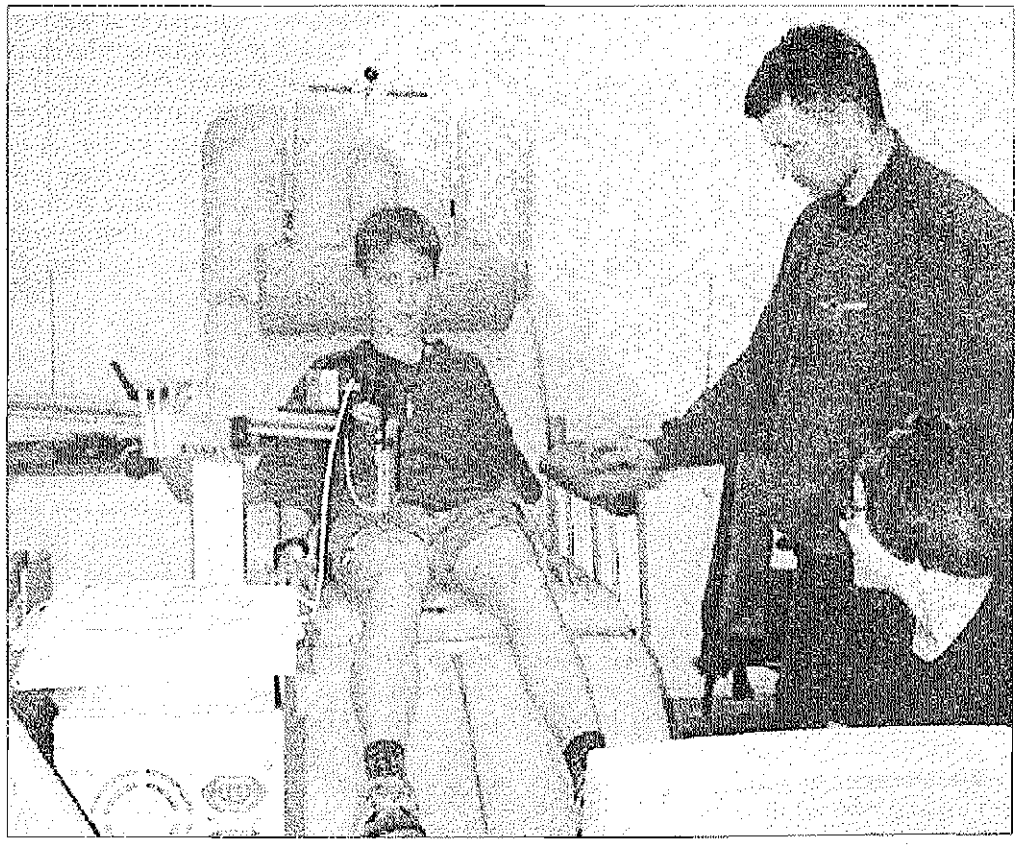

Fig. 1: Child's measurements: tensiomiographic measurements in the lab.
Sl. 1: Slika meritev otrok: primer meritve tenziomiografije (TMG) v laboratoriju.

Besides the fact that a large portion of the structure of the child's motor space is related to different forms of coordination (the role of the informational component of movement) and the fact that balance (adaptation) functions as a filter in the child's performance of movement, energetically supported by a basic level of strength, the realization of motor tasks is significantly subjected also to child's cognitive activity. Interrelations and contributions of the above mentioned dimensions enable a child to perform motor tasks and to solve motor problems until other motor abilities (coordination, strength, balance, speed, flexibility, precision) are differentiated in the child's development. These are the motor abilities that represent the basis in the realization of adult's motor efficacy along with functional predisposition (persistence). The development and consequently the differentiation of the central nervous system are crucial to this process.

Discussing the dimension of coordination in further detail we should point out its double form of occurrence: the inter-muscular and the intra-muscular forms. The former is particularly important in the realization and activation of various kinetic chains involved in the solving motor problems. The intra-muscular form is defined by the differentiation and the quantity of activation of different muscular fiber inside individual muscles involved in the solving motor problems. Both forms of occurrence of coordination are important to the control and the performance of motor tasks, their share depending on the nature and complexity of the motor problem. The structure of the child's motor space is integrative and we can assume that also the dimensions on the intra-dimensional level are still a great deal integrative as well. The differentiation of muscular fiber is completed when the nervous system matures.

The performance of a motor act and thus the solving of the motor problem involves the motor record (motor knowledge – programs), predisposition that are given by the level of motor abilities, the quality of transmission paths (neural and neuromuscular transmission – from a receptor to an executor) and executors – skeletal muscles as an important part of the motor system. Humans move in many different and complex ways on the range of fast and simple motor reactions to slow long-lasting movements in sequence. The variety in motor activity is granted by proper musculature.

Skeletal muscles form various types of muscular fiber, classified according to the speed of contraction and according to the level of contracting persistency: muscular fibre type I. – slow, persistent muscular fiber; muscular fiber type II. a. – rapid muscular fiber that is resistant to weariness; muscular fiber type II. b. – rapid muscular fiber that is not resistant to weariness. The types II. a. and II. b. are usually referred to as to single type of muscular fiber, namely, rapid muscular fiber. Slow and persistent (tonic) muscles are therefore mainly composed by slow muscular fiber (soleus, tibialis, *etc.)*, while rapid (fasic) muscles are mainly composed by rapid muscular fiber (triceps brachii, vastus lateralis, *etc.)*. Specific exercise influences mainly the development of rapid muscular fiber and thus rapid muscles. The contracting characteristics of skeletal muscles can be influenced either consciously (the influence of the training process and of the nature of motor activity), or unconsciously (neuro-muscular illness, injuries, *etc.)*.

The quantity and the quality of motor activity offered a child in different social environments influences the differentiation of characteristics of muscular fiber, as well as a congruent and logical development of skeletal muscles. The latter is extremely important for a balanced motor development of a child, a development of a healthy poise and locomotor sistem in general. At the same time it is crucial to successful integration and direction of children and youngsters in various sports disciplines.

METHODS

Measurement of skeletal muscles is a wide area of research on physiology and muscle functioning, interesting to doctors in diagnostics, rehabilitation and surgical operation, sports doctors as well as scientists. The measuring methods are based mostly on the measurement of physical extents related to the strength of the muscle. They are thus focused on the measurement of the lever in the joint moved by the muscle being measured. As such they are characterized by variability and non-selectivity, preventing us in the determination of contacting characteristics of individual muscles. Invasive measuring methods are more accurate, but they damage the tissue, their application being thus limited to an extremely small number of cases (muscular illnesses, research on corpses, etc.).

Tensiomiography (TMG) is a non-invasive measuring method used by our research team. It measures the radial muscle belly displacement (Valenčič & Knez, 1997). It provides selective measurements of radial muscle belly displacement as a response to single electrical stimulus. TMG has already been evaluated with torque measuring method and statistically significant correlation between type I percentage (obtained by histochemical techniques) and contraction time obtained by TMG has been established (Dahmane *et al.*, 2001). The sensor of displacement leans against the skin above the muscle being measured. The contraction of the muscle makes it fatter in a certain spot (muscle belly), due to the preservation of the muscle volume. The fattening of the belly muscle is tangible on the skin surface.

The results of our research so far are the measuring device, optimisation of the sensor positioning parameters and comparison of the TMG measuring method with the measurement of the lever in the corresponding joint,

histo-chemical analyses and electro-myographic shots. The reaction of the conscious and unconscious muscle contractions were being observed.

The preliminary research will be dedicated to the analysis of reaction of several muscles in 240 healthy children (125 boys and 115 girls), gathering elementary data and formulating a broader future research project. The measured children were 9.1 years old, standard deviation 0.4 years, they were healthy at the time of the measuring and in the immediate period before. We were interested in the differentiation of measured muscles into slow and rapid, the sample of muscles having been carefully selected (the most important muscles in the every-day motor activities in the sports class: sprinting, jumping, etc.). After having collected the signed agreement from the children's parents we started measuring the tensiomiography on selected muscles:

- m. biceps brachii (BB)
- m. vastus lateralis (VL)
- m. biceps femoris (BF)
- m. erector spinae (ES)

RESULTS AND DISCUSSION

In the twitch TMG response curve the following parameters have been defined: maximal displacement (Dm) and contraction time (Tc), see Figure 2. Maximal displacement assesses the maximal amplitude of muscle belly response and is strongly related to muscle force. Contraction time defined from 10% to 90% of maximal displacement achieved assesses the speed of muscle contraction.

The analysis of the data collected with tensiomiography, namely the time of contraction of the four selected muscles showed that vastus lateralis and erector spinae are rapid muscles, they are key muscles in the extension of the knee and lower back, respectively (Fig. 3). The biceps femoris, the muscle involved in the flexion of the knee, is the most important muscle in the achievement of the maximum running speed and was found to be a slow type of muscle. The biceps brachii is extensor of the elbow and was compared to lower limb muscles where we found out that was statisticaly faster than vastus lateralis and slower than biceps femoris.

The specifics of a child's movements are more likely walking and running than fast sprinting, therefore we expected differences in the contraction time of front and back muscles of femur. The hypothesis was that BF muscle was slower than VL muscle, which is used frequently in the child's every-day motor activity. The slower muscles are activated only during the maximum physical effort or in particular, unusual positions of the body. The data gathered show the choice of muscles to be crucial, especially the muscles involved in a wide range of motor activity, so that we can be able to give useful advice to children as to which sport discipline to join.

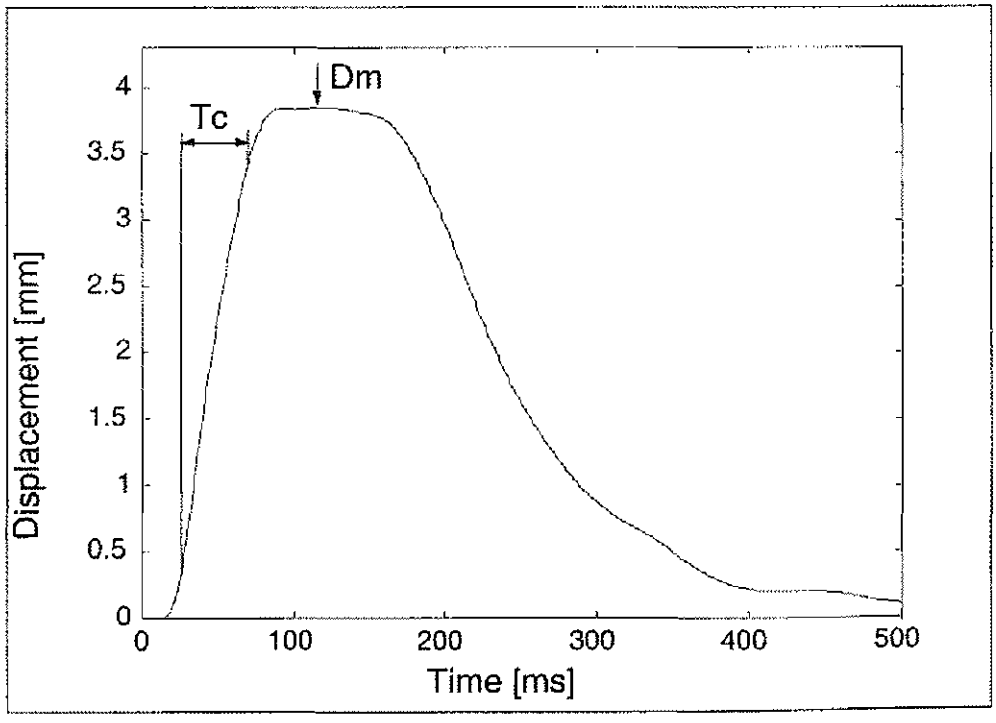

Fig. 2: TMG response and definition of TMG parameters.
Sl. 2: Odziv tenziomiografije (TMG) in definicija parametrov.

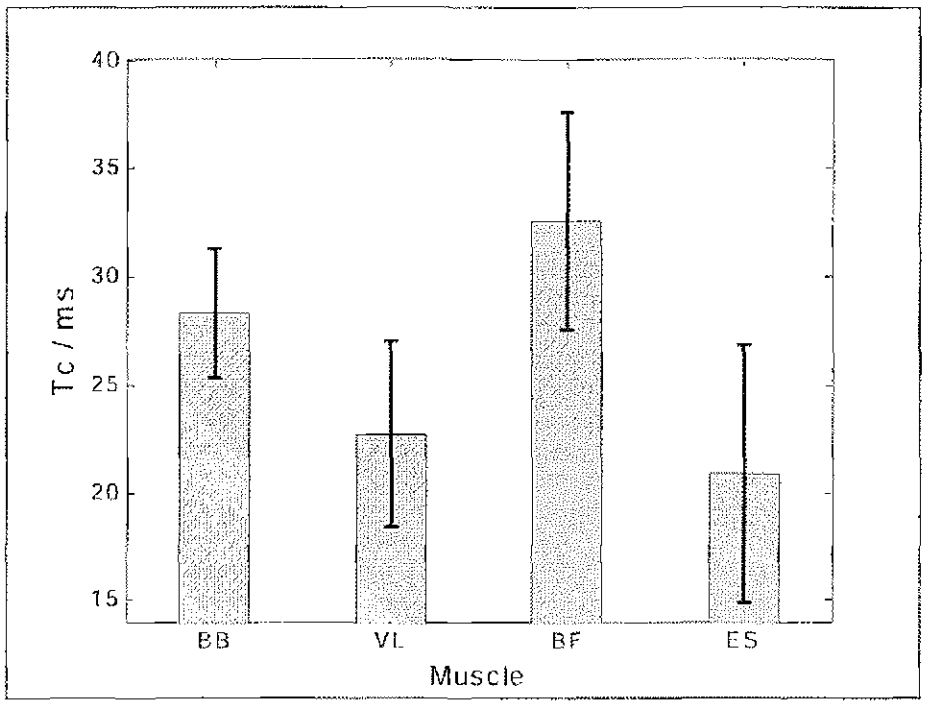

Fig. 3: Differences in contraction time (Tc) for the four different muscles measured on 240 subjects. Legend: BB – musculus biceps brachii, VL – m. vastus lateralis, BF – m. biceps femoris, ES - m. erector spinae.
Sl. 3: Razlika v času kontrakcije (Tc) za štiri različne mišice, izmerjene na 240 osebkih.

CONCLUSIONS

The data gathered show the level of passing from every-day motor activity over to the field of sport participation. Such data will allow us to advise children as to which sport discipline to join.

As it has already been stated, the preliminary research that has been carried out gave us an elementary database and will serve as a basis for larger research project to determine the role of the biomechanical characteristics of the skeletal muscles in the motor development of children. We will draw further conclusions on the basis of referential data gathered on a larger representative pattern of 900 children attending elementary schools in Slovenia. The results of the research will be analysed and they will be taken into consideration in the formulation of an atlas containing data about biomechanical characteristics of the children's measured skeletal muscles. Other data, such as children's sex and sports folder results will also be taken into account. The data in the atlas will serve as a basis for comparisons of measured individuals and average results in healthy children.

The reaction time of skeletal muscles is determined by the genetics, the physical practise can change the composition of the muscle only partially. It is every adult's wish to raise a healthy, normally developed and properly educated child. Strictly medically and statistically he should be within the normal range of value according to his age and sex. Our research is set to determine the normal ranges and values regarding the biomechanical characteristics of skeletal muscles, to discover whether the motor development is symmetrical from the point of view of the biomechanical characteristics of skeletal muscles, what are the deviations and probabilities. Early measurements of skeletal muscles could become a means of discovering eventual deviations in the physical and motor development of a child in the early stages, later it could help directing children in appropriate motor activities and sport disciplines in which they could achieve the best results. The composition of the biomechanical atlas of skeletal muscles of elementary school children would also acknowledge the important role of the measuring method, a result of a many years' research of national (Slovene) scientists.

VPLIV BIOMEHANSKIH LASTNOSTI NEKATERIH SKELETNIH MIŠIC NA GIBALNI RAZVOJ OTROKA

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POVZETEK

Količina in kvaliteta gibalne aktivnosti v katero otroka sili različno socialno okolje, vpliva tako na diferenciacijo lastnosti mišičnih vlaken, kot na skladen in smiseln razvoj skeletnih mišic. Ta je izredno pomemben za ravnovesje v otrokovem gibalnem razvoju, razvoj zdrave drže in lokomotornega aparata nasploh, ob tem pa tudi odločujoče vpliva na uspešno vključevanje in usmerjanje otroka, in mladostnika v posamezne športne zvrsti. Tako kot velja za celotno strukturo motoričnega prostora otroka lahko sklepamo, da je tudi znotraj posamezne dimenzije integrativnost še zelo velika. Popolna diferenciacija mišičnih vlaken se zaključi z razvojem živčnih centrov in poti. Za realizacijo gibalnega akta oz. rešitev gibalnega problema pa so, ob suportu, ki ga zagotavlja gibalni/motorični spomin (gibalna znanja – programi) in predispozicijah, ki jih nudi raven gibalnih/motoričnih sposobnosti ter kvaliteta prenosnih poti, zadolženi efektorji – skeletne mišice kot pomemben del gibalnega sistema. Človekovo gibanje je izredno raznovrstno in kompleksno od hitrih enostavnih motoričnih reakcij do dolgotrajnih počasnih zaporednih gibanj. Primerna muskulatura mu omogoča to raznoliko aktivnost.

Merilna metoda tenziomiografija (TMG), ki jo uporablja raziskovalna skupina, je neinvazivna merilna metoda, ki temelji na merjenju radialnega premika trebuha mišice. Senzor premika je prislonjen na kožo nad merjeno mišico z začetnim pritiskom. Ko se mišica skrči, se zaradi ohranitve volumna mišice na določenem mestu odebeli (trebuh mišice). Odebelitev trebuha mišice lahko zaznamo na površini kože. Večina uporabljanih merilnih metod temelji na merjenju fizikalnih veličin, ki so povezane s silo mišice. Takšna metoda je merjenje navora v sklepu, ki ga merjena mišica premika. Slabost takšnih metod je poleg variabilnosti tudi neselektivnost metode, zato ne moremo določiti kontraktilnih lastnosti ene same mišice. Bolj natančne so invazivne metode merjenja, ki poškodujejo tkivo in njihova uporaba je omejena na zelo ozek krog primerov (mišična obolenja, študije na kadavrih, itd.).

V raziskavi, ki bo med drugim služila za nabor informacij in zasnovo širšega raziskovalnega projekta na vzorcu otrok, smo analizirali odzive več mišic pri 240 zdravih otrocih (125 dečkov in 115 deklic). Merjenci so bili stari 9,1 leta, standardna deviacija 0,4 leta, vsi zdravi in brez prebolelih bolezni v kratkem obdobjem pred meritvijo. Zanimala nas je diferenciacija merjenih mišic na počasne in hitre pri otrocih te starosti, pri tem smo vzorec mišic izbrali skrbno in upoštevali najpomembnejše mišice za vsakodnevno gibalno aktivnost otrok pri pouku športne vzgoje (šprint, skoki). Po pisni privolitvi, ki smo jo pridobili s strani njihovih staršev smo izvedli meritve tenziomiografije na izbranih mišicah. Dobljeni podatki kažejo, da je potrebno skrbno izbrati vzorec mišic, predvsem tistih mišic, ki so značilne predstavnice kar najširšega spektra gibanja, da lahko otrokom kar najbolj svetujemo pri vključevanju v različne športe.

Ključne besede: tenziomiografija, skeletne mišice, električna stimulacija, osnovnošolci, atlas skeletnih mišic

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