DIFFERENTIATION OF SKELETAL MUSCLES IN 9-YEAR-OLD CHILDREN

Rado Pišot[1,2], Katarina Kerševan[3], Srdjan Djordjević[3], Vladimir Medved[4], Jernej Završnik[2] and Boštjan Šimunič[3]

[1]*Faculty of Education, University of Primorska, Koper, Slovenia*
[2]*Science and Research Centre, University of Primorska, Koper, Slovenia*
[3]*Faculty of Electrical Engineering, University of Ljubljana, Slovenia*
[4]*Faculty of Kinesiology, University of Zagreb, Croatia*

Conference paper
UDC 611.7:796.071.5-053.5

Abstract:

Motor activity in childhood is extremely important for the general development of a child, yet there is still not enough information about children's motor development. Contractile properties of skeletal muscles in children mainly reflect their inherited muscle characteristics. In early childhood the muscular structure is made mostly of slow-twitch muscular fibers. The finer motor abilities follow gradually from age three onwards when the muscular fiber is classified into slow-twitch, rapid and fast-twitch. The fastest development of this classification (muscle differentiation) takes place until the age of three and continues until the end of puberty.

In this study muscles of 187 healthy 9-year-old children were assessed using a non-invasive and selective measuring method called tensiomyography (TMG) in order to estimate the stage of differentiation of their skeletal muscles. TMG enables selective measurements of radial muscle belly displacement as a response to a single electrical stimulus.

The children measured were involved in this study after written consent had been obtained. TMG data were calculated on selected muscles: *m. biceps brachii, m. vastus lateralis, m. biceps femoris* and *m. erector spinae.* After TMG measurements had been carried out, each child performed a 14-metre sprint velocity test.

TMG parameters were calculated and compared in three groups, namely, the ten fastest children, the ten slowest children and the average result of all the children measured. The ten fastest children had a smaller sum of delay time and contraction time, which correlates with a higher percentage of fast-twitch muscle fibers. They also had a significantly higher level of muscle activation.

Key words: *tensiomyography, electrical stimulation, contractile properties*

DIE DIFFERENZIERUNG VON SKELETTMUSKELN BEI DEN NEUNJÄHRIGEN KINDERN

Zusammenfassung:

Die motorische Betätigung in Kindheit ist äußerst wichtig für die allgemeine Entwicklung eines Kindes. Trotzdem verfügt man immer noch nicht über genügend Informationen über die motorische Entwicklung der Kinder. Die kontraktile Eigenschaften der Körpermuskel bei Kindern zeigen meistens ihre vererbten Muskeleigenschaften. In frühester Kindheit besteht die Muskelstruktur meistens aus langsamreagierenden Fasern. Die Feinmotorik entwickelt sich allmählich vom dritten Lebensjahr an, wenn die Muskelfasern in langsamreagierende, rapide und schnellreagierende Faser eingeteilt werden. Die schnellste Entwicklung dieser Muskeldifferenzierung findet bis zum dritten Lebensjahr statt und setzt bis zum Pubertätsende fort.

In dieser Studie wurden 187 gesunde neunjährige Kinder eingeschätzt mit Hilfe einer nicht-invasiven und selektiven Messmethode, der s.g. Tensiomyographie (TMG), um die Differenzierungsphase der Skelettmuskeln zu bestimmen. Die TMG ermöglicht selektive Messungen der radialen Muskelbauch-verschiebung als Antwort auf einzelnen elektrischen Stimulus.

Die Kinder nahmen an der Forschung teil, nachdem man eine schriftliche Einwilligung bekam. Die TMG Daten waren auf ausgewählten Muskeln berechnet: M. biceps brachii, M. vastus lateralis, M. biceps femoris und M. erector spinae. Nachdem die TMG-Messungen durchgeführt wurden, wurde jedes Kind einem 14--Meter-Sprint Geschwindigkeitstest unterzogen.

Die TMG Parameter waren berechnet und in drei Gruppen verteilt - die zehn schnellsten Kinder, die zehn langsamsten Kinder und der Durchschnittswert aller gemessenen Kinder. Die zehn schnellsten Kinder haben eine kürzere Verzögerungs- und Kontraktionszeit, was dem höheren Anteil der schnellreagierenden Faser entspricht. Sie haben auch eine wesentlich höhere Muskelaktivierung.

Schlüsselwörter: *Tensiomyographie, elektrische Stimulation, kontraktile Eigenschaften*

Introduction

The development of a child results in the qualitative changes in his/her psychosomatic status. 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 mostly hereditary, therefore, we are almost unable to interfere with the sequence of abilities and readiness for action. However, providing a child with an experience-rich environment will help him/her develop certain forms of activities faster and with a stronger intensity.

In early childhood mainly the rough motor abilities are developed, the finer motor abilities follow gradually from the age of three onwards. In the early stages of motor development the muscular structure is made mostly of slow-twitch muscular fibers, involved in slow, major motor units with a high innervation number that allow a child to perform rough and inaccurate movements. A very important event of a child's motor development and skeletal muscle differentiation is the moment when the child begins to walk. Some sports scientists and coaches statistically believe that athletes with more fast-twitch fibers were crawling for a much longer time. This is rather the egg--chicken issue, as no one has proved yet if a child who has more slow-twitch fibers, will start to walk earlier, or is the time-factor the reason why a child who crawls longer has more fast-twitch fibers. A finer correction of movement is performed by means of the minor, rapid motor units. In the further stages of the child's development the muscular fibers are classified into slow-twitch, rapid and fast-twitch ones. The fastest development of this classification takes place until the age of three and continues until the end of puberty. This development progresses in correlation with – hypothetically – the effectiveness of the functioning of the individual centres in the central nervous system and the mechanisms that control and co-ordinate the functioning of the peripheral system. The control of the peripheral system is an outcome of the processes of learning, which coincides with the child's susceptibility and development stage of the whole organism.

On the basis of physiological, psychological and neurological findings, Luria (1976) developed the theory of the functional organization of the brain and its systems. He divided the brain into 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 three blocks. In each of the three brain blocks there is a hierarchical 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 is crucial in the creation of the most demanding forms of activities and makes possible the coordinated work of the cortical analysers. Its function is to integrate the cortex of the cerebrum. These complex areas of the cortex are the last to mature. The myelination ("maturation" of the nervous paths) of the primary zones is accomplished early, while the myelination of the secondary and of the tertiary zones is accomplished approximately at the age of seven or even later (Abernethy et al., 1997).

In early childhood the child is very susceptible to impulses from the environment. The influence of motor activities on his/her development as a whole is most important at this age (until the age of five); after that it gradually decreases. Motor activity is crucial to a young child since it integrates all the 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, 2000), as well as in the formation of the child's personality as a whole.

The performance of a motor act and thus the solving of a motor problem involve the motor knowledge – program, predispositions that are given by the level of the motor abilities, the quality of transmission paths (neural and neuromuscular transmission) and executors – skeletal muscles as an important part of the motor system.

Each muscle contains a combination of different fiber types, that are categorized as fast--twitch or slow-twitch. There are mechanical differences in the response of slow- and fast-twitch muscle fibers categorized by its fiber type. Slow--twitch or type I, oxidative muscle fibers are red due to the high content of myoglobin in the muscle. These fibers have a longlasting contraction time and are well suited for prolonged, low-intensity work. Endurance athletes usually have a higher quantity of slow-twitch fibers. Fast-twitch or type II fibers have a short contraction time, and may further be chategorized into type IIa, oxidative--glycolytic, and type IIb, glycolytic. The type IIa is a red muscle fiber known as the intermediate fast-twitch fiber because it can sustain activity for long periods, or it can contract with a burst of force and then fatigue. The white, type IIb fiber provides a rapid force production and then becomes fatigued quickly.

Musle fibers cannot split themselves to form completely new fibers. Every more intensive exercise or work causes some fiber destruction and these fibers are substituted by another new fiber of the same type. Muscle adaptation during a specific training process could also cause some minor fiber type changes but usually just within the single fiber type group. Type IIc fibers are by their mechanical contractile properties somewhere in between type IIa and Type IIb and are to be included into one of those two types. Muscle like the *m. biceps femoris* has more type IIc fibers, which are adaptable to the highest range. However, as people age, they degeneratively lose muscle fibers, but they never gain new ones. So, a muscle can become more massive only when its individual fibers become thicker, which is known as muscle fiber hypertrophy.

Two of the most fundamental areas of study in skeletal muscle research are involved with planning exercises and other stimuli that would cause muscles to become enlarged, and in studying how such activities can convert muscle fibers from one type to another. Measurement of skeletal muscles is a wide area of research involving physiology and muscle function. In this study, the muscles were assessed using a new, rather non-invasive and selective measuring method called tensio-myography (TMG) (Valenčič & Knez, 1997). It enables selective measurements of the radial muscle belly displacement as a response to a single electrical stimulus from which TMG based parameters are calculated and the contractile properties of the muscles measured are determined.

Methods

The study involved 187 healthy 9-year-old children (98 boys, 9 yrs., 139.8±6.44 cm, 34.9±6.98 kg; 89 girls, 9 yrs., 140.59±6.37 cm, 33.6±7.29 kg). Its purpose was to estimate the stage of differentiation of their skeletal muscles. The differentiation was assessed with the TMG method, based on the muscle contracting principle. As a response to a single electrical stimulus the muscle belly enlarges. Radial enlargement is measured with a displacement sensor (Fig.1). All the measurements were performed in isometric conditions, using bipolar surface electrical stimulation (pulse width 1 ms).

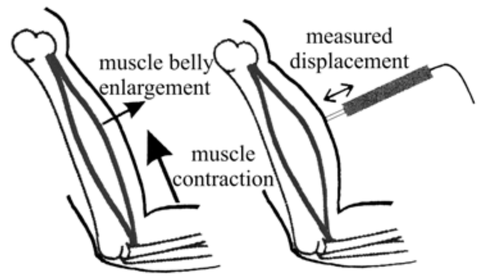


Figure 1. Principle of TMG measuring method.

In addition to being non-invasive, the TMG method is selective, it shows a low variability (below 5 %) (Šimunič, 2001), it is simple to apply, the data are available immediately after the measurement and the same measuring equipment can be used for all the skeletal muscles measurements.

TMG has already been evaluated (a) - biomechanically (Knez et al., 1994), (b) - histochemically (Dahmane et al., 2001) and (c) - neurophysiologically (Kerševan, 2002): (a) - correlation between muscle belly displacement and torque around the observed joint is statistically significant, (b) - statistically significant correlation between type I percentage, obtained by histochemical techniques, and the contraction time which was obtained by TMG was established (Dahmane et al., 2001), (c) - a comparison of the peak-to-peak value of M-wave (obtained by EMG) and the muscle belly displacement (obtained by TMG) during incrementally increasing intensity of surface electrical stimulation revealed a linear relationship between both parameters. The parameters, based on TMG (Fig. 2), used in the determination of the measured muscles' contractile properties, are as follows: D_m (maximum muscle belly displacement), T_d (delay time) 0 % – 10 % D_m, T_c (contraction time) 10 % – 90 % D_m, T_s (sustain time) 50 % D_m during contraction – 50 % D_m during the relaxation phase and T_r (relaxation time) 90 % – 50 % D_m.

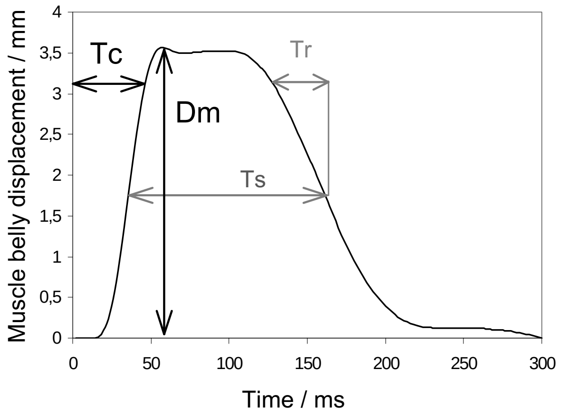


Figure 2. TMG based parameters.

The children measured were involved in this study after written consent had been obtained. TMG data were calculated on selected muscles: *m. biceps brachii* (BB - left, BB - right), *m. vastus lateralis* (VL – hand dominant side), *m. biceps femoris* (BF – dominant hand side) and *m. erector spinae* (ES - left, ES - right). After the TMG measurements were carried out each child performed a 14-metre sprint velocity test (7 m - approach, 7 m - recording segment).

Results and discussion

TMG parameters were calculated and compared in three groups, namely, the ten fastest children (sprint duration: 1.12±0.036s, mean±SD), the ten slowest children (1.51±0.035s) and the average result of all the children measured (1.28±0.09).

The ten fastest children had a smaller sum of T_d and T_c, which correlates with a higher percentage of the fast twitch muscle fibers (Dahmane et al., 2001). They also had a significantly greater displacement/activation (Table 1).

The characteristic forms of movement of children are walking and running rather than fast sprinting, thus in childhood, VL is more frequently used than BF. Therefore the differences in the contraction time of the front and back muscles of femur were expected, namely, we expected the muscle BF to contract slower than VL. Studies involving sprinters (Praprotnik et al., 2001) revealed a high correlation between the maximum running velocity and the contraction time of *m. biceps femoris* ($r = -0.598$, $p < 0.01$). In this study, such a correlation was neither expected nor demonstrated due to children's running technique and the limited sprinting performance in children.

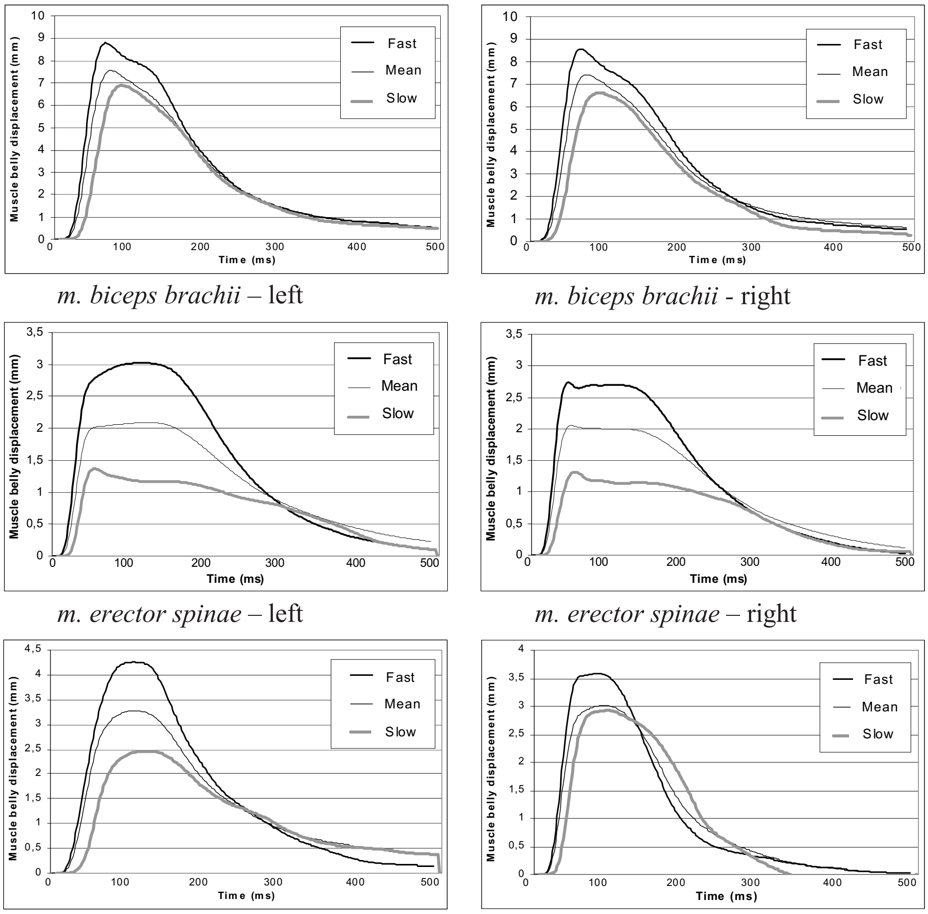
Figure 3 reveals a differentiation in ES contraction properties that probably results from the 89.1 % right sided children involved in the study. Figure 3 also reveals a higher level of differentiation in BB (upper limb) than in VL or BF (lower limb).

In Figure 3 the lateral difference between *erector spinae* responses of ten fastest runners is also evident. As most of the children were right-handed, and therefore with a left takeoff leg, we expected asymmetries in the lower back muscle contractile properties. The cross-connection between the left leg and right side of the lower back was evident from the shape of the ES response. ES on the right side has a spike at the end of contraction phase that is typical to the response of a faster muscle. In the response from the left ES we cannot observe this phenomenon. TMG method is the only one known that could separately measure each lateral side of the lower back muscles.

Table 1. TMG based parameters for three groups of 9-year-old children

	right BB			left BB			VL			BF			right ES			left ES		
	fast	slow	mean	fast	slow	mean	fast	slow	mean	fast	slow	mean	fast	slow	mean	fast	slow	mean
Tc+Td (ms)	53.5	63.2	57.7	53.8	60.3	57.7	49.3	53.2	50.4	63.6	69.0	63.8	44.3	44.2	46.7	41.2	45.3	44.3
Dm(mm)	8.9	7.0	7.7	8.7	6.7	7.5	3.7	3.0	3.1	4.3	2.5	3.3	3.1	1.5	2.3	3.0	1.4	2.3

Legend: BB – *m. biceps brachii,* VL – *m. vastus lateralis,* BF – *m. biceps femoris,* ES – *m. erector spinae*



m. biceps brachii – left

m. biceps brachii - right

m. erector spinae – left

m. erector spinae – right

m. biceps femoris

m. vastus lateralis

Figure 3. TMG responses in 9-year-old children.

In early childhood, the motor development as well as the development as a whole depends largely on the child's social environment. The philogenesis itself stimulates in humans the development of the upper extremities for manipulative purposes, and the development of the lower extremities for locomotion. However, some research data on the functional structure of motor abilities in children (Mejovšek, 1979; Madič, 1986; Pišot, 1998) reveal an important correlation between the complex manipulative motor tasks of the arms and the management of the movement of the legs as an integrated definition of a form of coordination (Pišot, 1998 – movement processing factor). In the child's motor development an experience-rich environment is crucial to the formation of his/her motor program.

Conclusions

From the results presented in this paper we can conclude that a shorter contraction time and a more intense activation of all the muscles measured (except for T_c of BF) in 9-year-old children are necessary for fast running, but they do not suffice. Different intensity and pattern of the measured muscles' activation indicate the presence of inter- and intra-muscular differentiation.

Considering the non-invasiveness and selectivity, TMG measurements of skeletal muscles in early childhood could be a useful methodology in the identification of irregularities in motor development and growth, research on muscle contraction properties, and in an early selection of talented young athletes.

References

Abernethy, B., Kippers, V., Mackinnon, L. T., Neal, R. J., & Hanraham, S. (1997). *The Biophysical Foundations of Human Movement*. Champaign, IL: The University of Queensland, Human Kinetics Publisher.

Dahmane, R., Valenčič, V., Knez, N., & Eržen, I. (2001). Evaluation of the ability to make a non-invasive estimation of muscle contractile properties on the basis of the muscle belly response. *Medical and Biological Engineering and Computing*, 39, 51-55.

Gardner, H. (1995). *The frames of mind*. Ljubljana: Tangram.

Kerševan, K. (2002). *Comparison of human biceps brachii's biomechanical and mioelectric response.* [In Slovenian.] (Unpublished master's thesis, University of Ljubljana). Ljubljana: Faculty of Electrical Engineering.

Kiphard, E. J. (1989). *Psychomotorik in Praxis und Theorie*. Guterslah: Flottmann Verlag.

Knez, N., Valenčič, V., Burger, H., & Marinček, Č. (1994). Repeatability of muscle belly displacement measurements [In Slovenian.] In F. Solina & B. Zajc (Eds.), *Proceedings of Electrotechnical and Computational Scientific Conference*, Portorož, Slovenia (pp. 340-343). Ljubljana: Slovenska sekcija IEEE.

Luria, A. R. (1976). *Osnovi neuropsihologije.* [*Basis of neuropsychology*.] Beograd: Nolit.

Madič, B. (1986). Odnos biomotoričkih dimenzija i kognitivnih sposobnosti dece predškolskog uzrasta. In *Zbornik radova* 10, (pp. 263–268). Niš: Filozofski fakultet u Nišu.

Mejovšek, M. (1979). Relacije kognitivnih i motoričkih sposobnosti. [Relations between cognitive and motor abilities.] *Kineziologija*, *9*(1-2), 83-90.

Pišot, R. (2000). The analysis of the structure of six-and-a-half years old children's motor space in the light of its development as a whole. *Kinanthropologica, Acta Univ. Carol., 36*(1), 67-78.

Pišot, R. (1998). Latent structure of the motor space of the six-and-a-half year old boys. [In Slovenian.] *Annales, Series Historia Naturalis, 9*(1=15), 119-132. Slovenia.

Praprotnik, U., Valenčič, V., Čoh, M., & Šimunič, B. (2001). Maximum running velocity is related to contraction time of muscle biceps femoris. [In Slovenian.] In B. Donne & N. J. Mahony (Eds.), *Proceedings of the International Sports Medicine Conference* (pp. 189-190). Dublin: Trinity College Dublin.

Šimunič, B. (2001). *Variability analysis of skeletal muscles' responses to electrical stimulation.* [In Slovenian.] (Unpublished master's thesis, University of Ljubljana). Ljubljana: Faculty of Electrical Engineering.

Valenčič, V., & Knez, N. (1997). Measuring of skeletal muscle's dynamic properties. *Artificial organs, 33*(3), 240-242.

Selected: December 15, 2003
Accepted: May 10, 2004

Correspondence to:
Prof. Rado Pišot, PhD
Faculty of Education Koper, University of Primorska
Cankarjeva ulica 5, 6000 Koper, Slovenia
Phone: +386 5 66 31 260, +386 41 687 423,
Fax: +386 5 66 31 268
E-mail: Rado.Pisot@pef.upr.si

DIFERENCIJACIJA SKELETNIH MIŠIĆA DEVETOGODIŠNJAKA

Sažetak

Uvod

Razvoj djeteta rezultira kvalitativnim promjenama psihosomatskog statusa, a temelji se na sazrijevanju živčanog sustava, što djetetu omogućuje prijelaz na višu razinu funkcioniranja. Proces sazrijevanja je uglavnom naslijeđen. Usprkos tome, moguće je pomoći djetetu u razvoju tako da brže usvaja i usavršava određene oblike aktivnosti u podražajima i raznolikim iskustvima bogatoj okolini.

U ranom djetinjstvu razvija se gruba motorika, dok se fina motorika razvija od treće godine nadalje. U ranim fazama motoričkog razvoja mišićnu strukturu čine uglavnom spora aerobna mišićna vlakna, uključena u rad sporih, velikih motoričkih jedinica s većim brojem inervacija koje djetetu omogućuju izvođenje grubih i manje preciznih pokreta. Finija korekcija pokreta provodi se manjim - brzim mišićnim jedinicama. U daljnjoj fazi razvoja djeteta, mišićna se vlakna dijele na spora, brza anaerobna i brza mješovita mišićna vlakna. Najbrži razvoj tako klasificiranih mišićnih vlakana, odnosno diferencijacija mišića događa se u trećoj godini života i traje sve do kraja puberteta. Taj se razvoj odvija u korelaciji s povećanjem učinkovitosti funkcioniranja pojedinih centara središnjeg živčanog sustava i mehanizama koji koordiniraju i nadziru rad perifernog živčanog sustava. Kontrola perifernog živčanog sustava rezultat je procesa učenja, što koincidira s djetetovom osjetljivošću i spremnošću da uči, kao i sa stadijem razvoja cjelokupnog organizma.

U ranom djetinjstvu dijete je vrlo osjetljivo na podražaje iz okoline. Utjecaj motoričkih aktivnosti na njegov ukupan razvoj najvažniji je u toj dobi (dobi do pet godina), nakon čega postupno opada. Motorička aktivnost izuzetno je važna za malo dijete zato što integrira sva područja izražavanja: motoričko, kognitivno, konativno, emocionalno i socijalno područje. Sva ta područja, kao sredstva potkrepljenja, igraju vrlo važnu ulogu u samom procesu učenja i u oblikovanju cjelokupne djetetove ličnosti.

Svrha ovog rada bila je procijeniti stupanj diferencijacije skeletne muskulature djece u dobi od 9 godina.

Metode

U istraživanje je bilo uključeno 187 devetogodišnjaka. Diferencijacija skeletne muskulature procijenjena je tenzomiografijskom metodom (TGM) koja se temelji na principu mjerenja kontrakcijskih svojstava mišića. Kao odgovor na jednostavni električni podražaj, trbuh mišića se poveća. Radijalno proširenje mjereno je senzorom za pomak. Sva su mjerenja provedena u izometrijskim uvjetima, korištenjem bipolarne površinske električne stimulacije (trajanje impulsa 1ms). Uz to što je prilično neinvazivna, metoda TGM je i selektivna, a pokazuje i niski varijabilitet (ispod 5%) (Šimunič, 2001), stoga je jednostavna za primjenu, a podaci su dostupni neposredno nakon mjerenja. Osim toga, ista oprema može se koristiti za sve vrste skeletnih mišića.

Parametri kontrakcijskih svojstava mišića koji se dobiju primjenom metode TGM jesu: Dm (maksimalni pomak trbuha mišića), Td (vrijeme kašnjenja) 0%-10%, Tc (vrijeme kontrakcije) 10%-90% Dm, Ts (trajanje kontrakcije) 50% Dm za vrijeme kontrakcije – 50% Dm u fazi relaksacije i Tr (vrijeme relaksacije) 90%-50% Dm.

Parametri TGM izračunati su na sljedećim mišićima: *m. biceps brachii* (BB – lijevi, BB - desni), *m. vastus lateralis* (VL - na strani dominantne ruke), *m. biceps femoris* (BF – na strani dominantne ruke) i *m. erector spinae* (ES - lijevi, ES - desni). Nakon što su na svakom djetetu izmjereni parametri, djeca su otrčala 14m sprinta (test brzine, 7m - zalet , 7m - segment mjerenja).

Rezultati

Parametri su izračunati i uspoređeni na razini tri grupe djece, točnije između grupe od desetoro najbrže djece (vrijeme sprinta: 1.12±0.036s, aritmetička sredina±standardna devijacija), zatim desetoro najsporije djece (1.51±0.035 s) i grupe s prosječnim rezultatom sve djece u primijenjenom testu brzine (1.28±0.09 s). Desetoro najbrže djece imalo je kraće ukupno vrijeme Td i Tc, što se povezuje s višim postotkom brzih mišićnih vlakana (Dahmane i sur., 2001). U grupi te djece također je dobiven značajno veći pomak /aktivacija.

Djeca puno više koriste uobičajene kretne strukture - hodanje i trčanje, od brzog trčanja (sprint), stoga se u djetinjstvu više koristi m. VL nego m. BF. Zbog toga smo očekivali razlike

u vremenu kontrakcije prednjih i stražnjih mišića femura, točnije, očekivali smo da će se m. BF kontrahirati nešto sporije od m. VL mišića. Istraživanja provedena na sprinterima (Prapotnik i sur., 2001) utvrdila su povezanost višeg reda između maksimalne brzine trčanja i vremena kontrakcije m. *biceps femoris* (r = - 0.598, p<0.01). U našem istraživanju takva korelacija nije ni očekivana ni dobivena, i to zbog slabije tehnike trčanja djece, a onda i zbog ograničenja u sprinterskoj izvedbi djece te dobi.

Iz dobivenih je rezultata također očigledna razlika između dominantne i nedominantne strane tijela u odgovoru *m. erector spinae* u grupi desetoro najbrže djece. Kako su ta djeca većinom bila dešnjaci te su se uglavnom odražavala lijevom nogom, očekivali smo asimetriju u kontrakcijskim osobinama mišića donjeg dijela leđa. Križna-korelacija lijeve noge i desne strane donjeg dijela leđa vidljiva je iz oblika odgovora m. ES. Šiljak signala m. ES na desnoj strani dobiven je pri kraju f faze kontrakcije, što je tipično za odgovor brze muskulature. Na osnovi odgovora lijeve strane m. ES nismo mogli opaziti taj fenomen. Metoda TGM je jedina metoda koja može odvojeno mjeriti svaku stranu muskulature donjeg dijela leđa.

Zaključak

Na temelju dobivenih rezultata može se zaključiti da su kraće vrijeme reakcije i veća aktivacija svih mjerenih mišića (osim za Tc m. BF) nužni za brzo trčanje devetogodišnje djece, što, međutim, nije i dovoljno. Različiti intenziteti i različiti obrasci mišićne aktivacije ukazuju na nazočnost među- i unutar-mišićne diferencijacije. Uzimajući u obzir neinvazivnost i selektivnost, možemo mjerenje skeletnih mišića metodom TGM u ranom djetinjstvu smatrati korisnom metodom za identifikaciju nepravilnosti u motoričkom rastu i razvoju te za istraživanje kontrakcijskih osobina mišića i za ranu selekciju mladih talentiranih sportaša.