BRAIN. Broad Research in Artificial Intelligence and Neuroscience
ISSN: 2068-0473 | e-ISSN: 2067-3957
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2020, Volume 11, Issue 4, Sup.1, pages: 46-61 | https://doi.org/10.18662/brain/11.4Sup1/155

Determination of Neuromuscular Control of the Upper Limbs in Children - Case Study

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Abstract: *The objective of this case study is to observe the existence of an anticipation mechanism at the muscle groups level of the upper limbs. We tried to highlighted this anticipation process by measuring the potential of surface electric for some muscle groups representing the kine-matic chain on the right side, involved in the motor action of catching a basketball and a 3kg medicine ball with two hands to the chest. We conducted a case study of a 13-year-old child, female gender. As a measurement method, we used surface electromyography signals of the EMG Trigno Delsys wireless system with 16 electrodes. We determined the moment when the muscles come into action by increasing the potential of surface electric and the moment when the action of catching the ball takes place, using the information provided by the accel-erometers incorporated in the sensors of the Delsys equipment used. Therefore, we obtained information about how different muscle groups come into action which helped us to get an idea of how the child's movement is structured. Based on results of accelerations and EMG signals acquired we have formulated conclusions regarding the neuromuscular control of the tested subject. We also planned for the future to test a larger group of participants in the study research of anticipation mechanism in children who do not practice any performance sports.*

Keywords: *structural anticipation; electromyography; catching a ball; motor action.*

How to cite: Camenidis, C.-M., Băițel, I., Oatu, A., Amzulescu, O., & Bidiugan, R. (2020). Determination of Neuromuscular Control of the Upper Limbs in Children - Case Study. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 11*(4Sup1), 46-61. https://doi.org/10.18662/brain/11.4Sup1/155

Introduction

The research into the mechanism of anticipating human motor behavior is a challenge for both PhD students and researchers in sports science and physical education, because of movement that require sending a nerve command in the motor cortex which is involved in controlling voluntary body movements to initiate a motor action. Voluntary movement controlled by the cortex expresses the human intention to initiate an action through a pre-existing motor program anticipating the movement.

According to Pailhours and Bonnard (1999, p.2160) the voluntary movement comes from a nervous command generated in the cortex which is called telekinetic, insofar as it expresses the intentions of the individual and where it may have different patterns due to the cognitive abilities of the human being.

According to Kandel et al. (2013, p. 862) the motor cortex although plays an essential role in controlling voluntary movements, its neurons do not function as spinal motor neurons whose unique role is to encode patterns of muscle activity. Instead, the motor cortex contains a heterogeneous population of neurons that contribute to several operations needed to convert an action plan into the motor controls that execute the motion pattern. The new evolutionary development in primates of a direct, monosynaptic projection on spinal motor neurons allows the primary motor cortex to control hand and finger movements in a uniquely skilled way. This feature was essential in acquiring the dexterity movements of the hand that only the upper primates possess and especially humans.

In this article we will highlight the values of an existing mechanism of anticipation due to the intention's effect of the predictive internal model (Kandel et al., 2013, pp.758-759) on the muscles. The effect of telekinetic anticipation of a motor pre-action could be depend on the degree of development of the motor program that the child of our case study may have.

From our point of view, the term of telekinetic anticipation in this context expresses the various voluntary movements to which we attribute an intentionality for the body in the action of catching a ball.

The objective of our case study is to highlight the telekinetic anticipation mechanism for the learning area of a motor task by using an electrophysiological measurement technique.

The phenomenon of anticipation from the electrophysiological techniques point of view, demonstrates that the anticipatory processes can be observed only with a certain difficulty and as disconnected manifestations

(Bernstein, 1967, p.162). The surface electromyography (EMGS) is used in biomechanics to highlight the control of muscle contraction during effort, especially to be able to understand the role played by each muscle group in structuring an effective motor gesture (Hillerin, 2011, p.31). These processes can be observed before the movement begins when the weak bioelectrical manifestation of tonic impulses, involuntary, is not masked by the much stronger potentials that accompany muscle activity (Bernstein, 1967, p.163).

An understanding of anticipatory muscle contraction in the development of motor control as "being about something" (Ohashi, 1997) could be observed using the Delsys Trigno EMG wireless system with 16 electrodes. It requires knowledge of human anatomy because EMGS provides data on the analysis of the processing and recording of electrical signals between two or more recording electrodes placed on the muscles (Delafield-Butt & Gangopadhyay, 2013).

Selection and placement of electrodes are important (Soltani & Vilas-Boas, 2016) because the Delsys Trigno EMG wireless system measures the electrical signal associated with neural muscle activation, being an experimental technique that provides information about what is happening physiologically in the nerves and muscles, as well as information about sequences or synchronization over time of a several muscles activities. The importance of EMG wireless system is that it provides an objective assessment of when a muscle is active or not because it reflects electrical activity in the muscle fibers of the activated motor units (MU) where the electrical signal is proportional to the degree of muscle activation and it spreads over the muscle fibre surface (Hunter et al., 2002).

According to Hillerin (2011, p.34), electromyography is an application about the utility of understanding electrical phenomena for the performance sports domain and effort in general, as well as usefulness in physical education where the phenomenon of anticipation exists and continues to be the subject of research, but it is difficult to determine given the time of the order of milliseconds that requires advanced technical equipment to measure it.

There are other authors who say that the central nervous system can perform anticipatory adaptations in terms of advance adjustment of the excitation of all the sensory and motor elements used where the physiological component (biochemical or electrical) ensures the production of the respective behavior, and the morphological component (type of neurons, synapses and neural circuits) supports the physiological manifestation (Berthoz, 1993, p.379; Dănăilă & Golu, 2000, p.11; Dima et al., 2007, p.84, p.438, p.1565; Epuran, 2011, pp.30-31, pp.269-270; Kandel, 2013, p.746-747, Forestier, 2018; Pailhous & Bonnet, 1999, pp.2159-2160; Sbenghe, 2002, p. 350; Williams, 2006, p.105, p.23).

We also mention other researches conducted over time which has shown that the posterior parietal cortex is involved in motor-sensor integration processes which allows the generation of predictive models, as well as the real-time estimation of the segmental position and the identification of the discrepancies between the anticipated consequences versus real driving commands (Baumann et al., 2015; Brenton & Müller, 2018; Bongaardt & Meijer, 2000; Botezatu & Andrei & Hillerin, 2014; Buckner et al., 2011; Gau et al., 2020; Macovei & Hillerin, 1997; Marin et al., 2015).

Research hypotheses

1. If we use surface electromyography (EMGs) then we could highlight the phenomenon of functional anticipation on the arm muscles in the execution of an absorption movement to catch a ball.

2. The measurement of the anticipation contraction is different both in relation to the task to be performed and for the muscle groups involved.

3. If we have different work tasks, then the anticipation time could also be different.

Research methods

The main research methods used were as following:

- the bibliographic studying;
- the observation method;
- the laboratory experiment;
- the case study
- the data collection and data processing by filtering and RMS (the root mean square);
- the mathematical method;
- the graphic representation;
- method of data analysis and interpretation.

The subject of the research was a child 13-year-old, female gender, right-handed, who does not attend at any performance sport training and has no history of motor or neurological dysfunction. The participant was informed of the characteristics of the research and brought an informed written consent document signed by the parent.

1. The experiment took place at the Biomotor Laboratory of the National Institute for Sports Research, located on Bucharest, strictly following

the rules of the World Health Organization (2020).

The work methodology was established as follows: before catching, the participant stood in a staggered stance with the legs apart and knees slightly bent, arms bent in front of the chest and hands with fingers slightly rounded and ready to catch the ball. In order to help the participant to perform the exercises, a researcher was located 2 m in front of her, with a similar staggered stance. The participant catches the ball with two hands to the chest by an absorption movement, hold the ball for 1-2 seconds and after that she throws the ball back to researcher. The participant was instructed to catch and throw the ball as fast as possible. In both exercises with the two different types of ball, the ball was caught in front of the chest and thrown directed towards the researcher and both legs were in contact with the ground throughout whole trial.

An accommodation period consisting of three repetitions of each exercise was performed prior to data collection. The participant was verbally instructed by the researcher on correct catching and throwing technique. A 3 min rest period between exercises was given to avoid muscular fatigue.

The participant performed three catches of the basketball and three catches with the medicine ball.

Results

Surface electromyography (EMG) signals were collected by using the EMG Trigno Delsys wireless system with 16 electrodes. An accelerometer is also incorporated in the composition of each sensor unit. We used 11 electrodes that were placed on the main muscle groups from kinematic chains involved in the absorption and propulsion movement of catching and throwing the ball to / from the chest with both hands.

The following upper limbs and trunk muscles and locations were used: rectus abdominis (RA); external oblique (EO); pectoralis major (PM); flexor carpi radialis (FCR); biceps brachii (BB); extensor digitorum (ED); anterior deltoid (AD); trapezius middle fibers (TMF); thoracolumbar fascia (TF); latissimus dorsi (LD) and the triceps brachii (TB).

A topographic marking of the different anatomical points was carried out to facilitate the placement of the electrodes and the skin zones for electrode locations were cleaned with an alcohol swab in order to reduce impedance. Then the surface electrodes were placed parallel to the muscle fibers to begin their electrical signals recording.

Using the dedicated software of the Trigno DelSys system, the information acquired using the EMG sensors was processed by filtering the signal for both acceleration and EMG signal and RMS (the root mean square) and then the data collected after filtering was exported to Excel.

In this regard, we illustrated graphically the evolution of the acceleration over time and the surface electromyography (EMG) signals for the muscles monitored in order to observe what happens before catching the ball (figure 1). From all the acceleration signals acquired we have chosen to use the one recorded from the sensor fixed on ED because it was the first segment that moved when the ball was caught.

Following the curves carefully, we identified the time t_0 when the forearm begins to move. On the x-axis of time in the surface electromyography (EMG) graph, we marked t_0 moment and tracked the muscle activity that precedes it, which is characteristic of the movement anticipation.

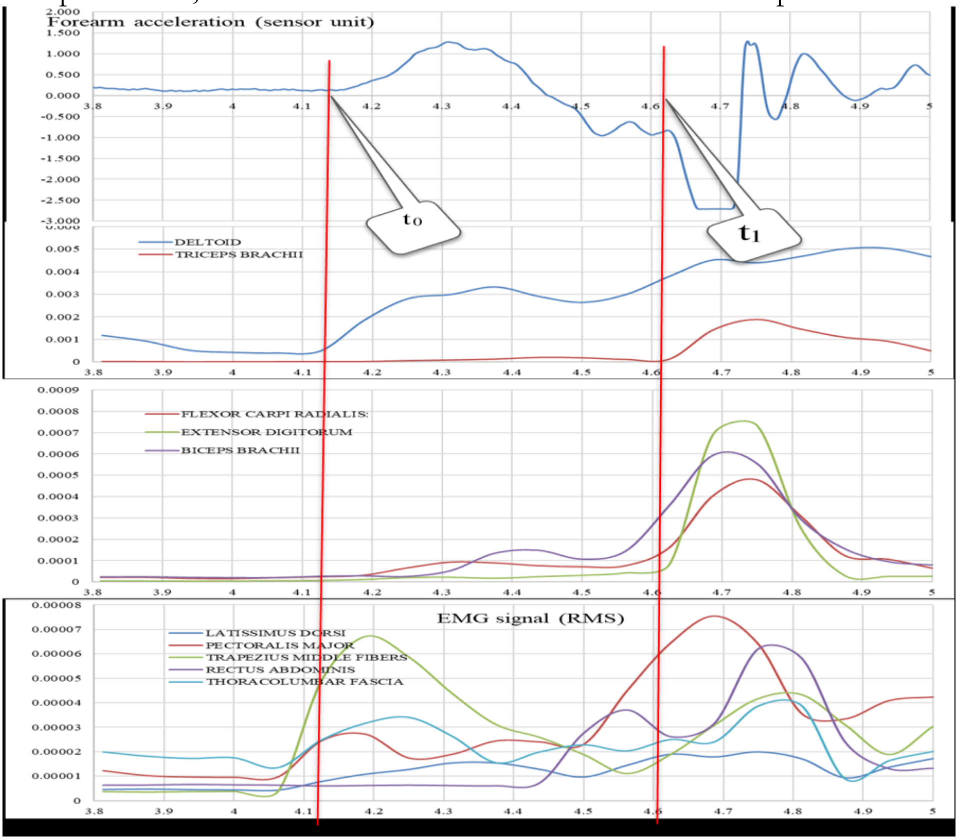

Figure 1. Acceleration and EMG signals for catching a 3kg medicine ball

Source: figure arising from the original research activity

On the acceleration graph, we analyzed the first decrease of the forearm acceleration in order to mark the t_1-moment corresponding to the contact with the ball. The muscle activity between these two moments of time, t_0 and t_1, represents the area of the contact anticipation, respectively the muscles preparation for contact. There are contractions between the interval t_0 - t_1 to a small extent for muscles monitored (TB, FCR, ED, BB and RA).

In order to participate in the preparation of contact with the ball, also have contractions during this time the muscles AD, TMF, TF and PM. Even before catching the medicine ball the activity of all muscle groups has been intensified. We can see that certain muscles groups come into action before the t_0 reference point like AD, TF, PM, TMF rather than TB, FCR, ED, BB (which have muscular coordination in the same time - figure 2). RA does not come into action before the same reference point shown above. Figure 2 shows how the muscle groups of TB, FCR, BB and ED acted. At t_1-moment was made the synchronization of time variation curves of the potential electrical of the muscles involved.

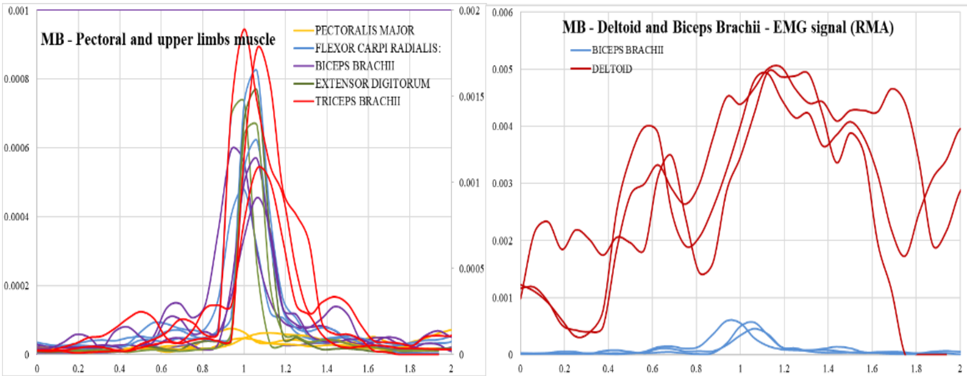

Figure 2. Muscular coordination for catching a 3kg medicine ball
Source: figure arising from the original research activity

Following the data acquired and the graphs presented, we identified the reference points of the anticipation time values at t_0 and t_1 when the first movement of the forearm begins for each of the three catches of the ball.

In this regard, we have calculate the movement timing from the first contraction until the contact with a 3kg medicine ball (table 1).

Table 1. The anticipation time for catching a 3kg medicine ball
Source: original data resulting from research

Time	1st Catching	2nd Catching	3rd Catching
t_0 [s]	4.148	8.164	12.814
t_1 [s]	4.634	8.643	13.891
t_1 - t_0 [ms]	504	521	923

Once we discovered these reference points, we were able to observe in the participant how its muscles have prepared for the trials performed.

Table 2 shows the maximum values of the EMG signals measured which are expressed in microvolts [μV] for each muscle involved in every of the three actions of movement. These values represent the maximum recorded before t_0 and between $t_0 – t_1$.

Table 2. The potential of surface electric for three catches of a 3kg medicine ball
Source: original data resulting from research

Catch	Surface electical potential	AD	TB	FCR	ED	BB	EO	LD	PM	TMF	RA	TF
1	V_{max}	5034	1890	479	734	595	62	20	75	67	62	39
	V_{max} (t_0–t_1)	3325	202	162	82	359	52	19	65	67	37	34
	V_{max} before t_0	1182	26	24	7	26	12	8	24	49	7	25
	% t_1-t_0	66	11	34	11	60	84	95	85	100	60	88
	% before t_0	23	1	5	1	4	19	39	32	73	11	64
2	V_{max}	4924	1082	822	766	456	606	19	47	64	73	46
	V_{max} (t_0–t_1)	3987	288	111	41	169	245	15	43	55	8	36
	V_{max} before t_0	1229	46	33	12	42	38	7	19	4	7	18

	% t_1-t_0	81	27	14	5	37	40	80	91	85	9	78
	% before t_0	25	4	4	2	9	6	36	40	7	96	39
3	V_{max}	4956	1778	621	664	568	355	16	63	119	21	36
	V_{max} (t_0–t_1)	3482	248	70	21	80	109	12	20	119	21	32
	V_{max} before t_0	3097	77	33	13	26	108	12	19	22	21	25
	% t_1-t_0	70	14	11	3	14	31	73	32	100	97	88
	% before t_0	63	4	5	2	5	31	76	30	19	100	70

Abbreviations: RA = rectus abdominis; EO = external oblique; PM = pectoralis major; FCR = flexor carpi radialis; BB = biceps brachii; ED = extensor digitorum; AD = anterior deltoid; TMF = trapezius middle fibers; TF = thoracolumbar fascia; LD = latissimus dorsi; TB = the triceps brachii.

Figure 3 shows the same synchronization for the trunk and the abdominal muscle groups area. The overlap was not so good, which is a sign that every time the subject has organized its movements differently (as I said, the 13-year-old subject does not practice any sport in an organized way).

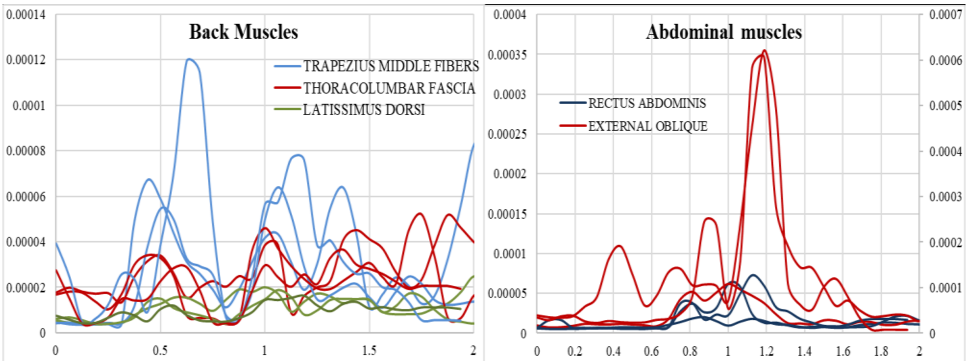

Figure 3. Muscular contraction for trunk and abdominal muscles for catching a 3kg medicine ball

Source: figure arising from the original research activity

Figure 4 shows the percentage calculation for maximum contraction recorded for the three catches of a 3 kg medicine ball.

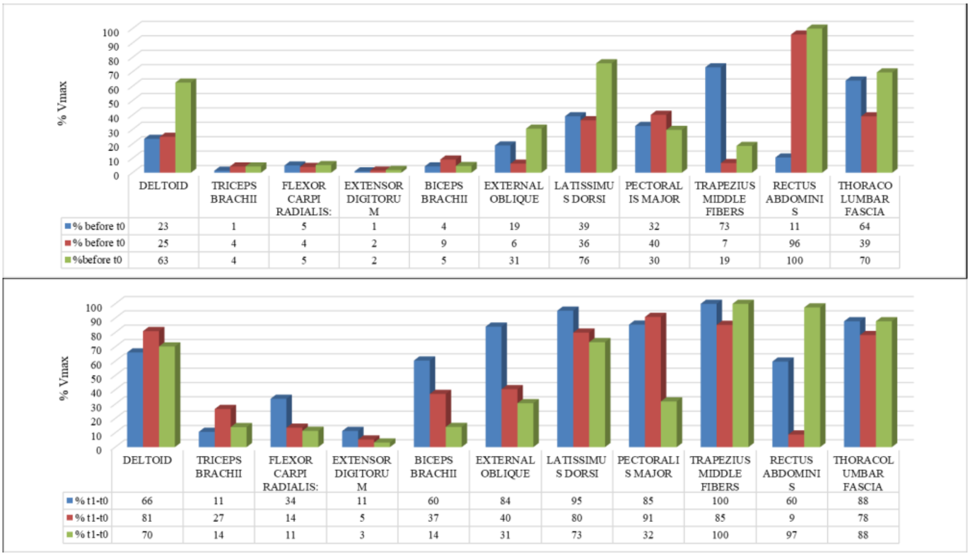

Figure 4. Percentage of maximum contraction recorded before t_0 and between t_0 - t_1.

Source: figure arising from the original research activity

There is a contraction of anticipatory movement for three of the four muscle groups (TMF, TF and LD) presented above and, more strongly, another contraction in contact anticipation with the ball between t_1 - t_0 for the TB and BB muscles.

In the same way as for the medicine ball, we processed the data for catching a basketball. After we gained the data acquisitions we marked the reference points for the t_0 and t_1-moment timing in order to observe in the participant's motor behavior how its muscles have prepared for the trials performed. The results obtained are represented in Table 3 for the time intervals delimited by the t_0 and t_1 moments.

Table 3. The anticipation time for catching a basketball
Source: original data resulting from research

Time	1st Catching	2nd Catching	3rd Catching
t_0 [s]	1.515	6.173	12.008
t_1 [s]	1.931	6.767	12.234
t_1 - t_0 [ms]	416	594	222

Table 4 shows the maximum values of the EMG signals measured which are expressed in microvolts [μV] for each muscle involved in every of three motor actions representing the maximum recorded before t_0 and between $t_0 – t_1$.

Table 4. The potential of surface electric for three catches of a basketball
Source: original data resulting from research

Catch	Surface electrical potential	AD	TB	FCR	ED	BB	EO	LD	PM	TMF	RA	TF
1	V_{max}	5042	57	193	142	2523	37	23	88	32	33	27
	V_{max} (t_0–t_1)	3992	57	155	82	876	37	22	73	32	33	27
	V_{max} before t_0	649	7	27	7	1212	8	7	17	19	11	11
	% t_1-t_0	79	100	80	58	35	100	94	83	100	98	100
	% before t_0	13	12	14	5	48	23	29	19	60	32	41
2	V_{max}	4948	51	159	90	2146	46	52	70	59	52	34
	V_{max} (t_0–t_1)	3017	22	73	22	625	13	10	21	38	19	34
	V_{max} before t_0	1319	8	26	6	18	13	6	17	14	16	15
	% t_1-t_0	61	42	46	24	29	29	20	31	64	36	100
	% before t_0	27	16	16	7	1	28	11	24	24	32	44
3	V_{max}	5031	106	724	145	2785	42	98	121	84	39	35

V_{max} (t_0–t_1)	4352	74	115	42	910	18	45	31	84	28	35
V_{max} before t_0	1540	7	23	6	37	13	6	21	71	11	15
% t_1-t_0	87	70	16	29	33	42	46	26	100	73	100
% before t_0	31	7	3	4	1	31	6	18	84	28	42

Abbreviations: RA = rectus abdominis; EO = external oblique; PM = pectoralis major; FCR = flexor carpi radialis; BB = biceps brachii; ED = extensor digitorum; AD = anterior deltoid; TMF = trapezius middle fibers; TF = thoracolumbar fascia; LD = latissimus dorsi; TB = the triceps brachii.

Figure 5 shows the surface electromyography (EMG) signals for the TB, FCR, BB and ED muscles. To the right of the image are the variance curves of the surface electrical potentials for deltoid and biceps brachii. The timing was done all, the one that marks the contact with a basketball. It is observed how a pattern of movement is observed somewhat, but there are also variations that indicate a disorder in the organization of the movement.

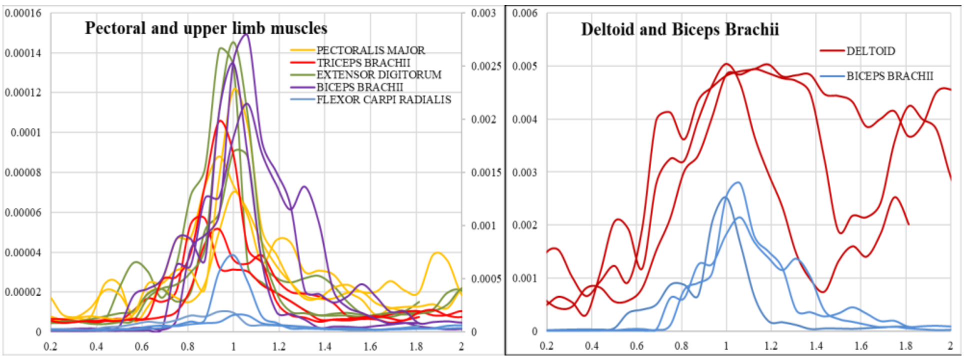

Figure 5. Muscular coordination for catching a basketball
Source: figure arising from the original research activity

Figure 6 shows the muscle activity recorded for the TMF, LD and TF muscle (left image) and for the RA and EO muscles (right image).

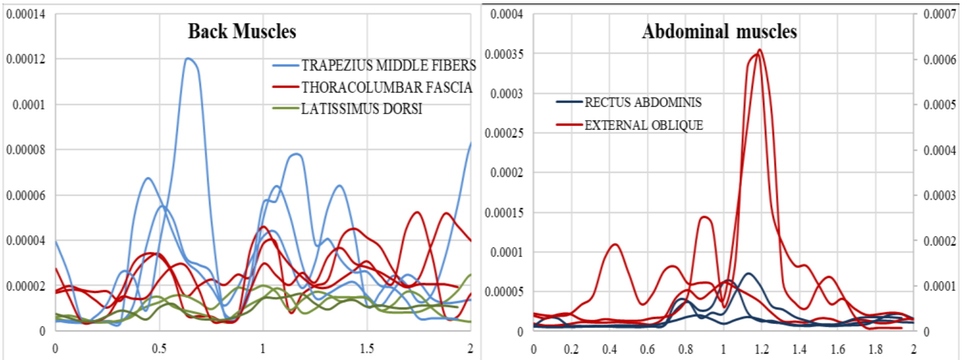

Figure 6. Muscular coordination for Back and abdominal muscles for catching a basketball

Source: figure arising from the original research activity

Figure 7 shows the calculation of percentages for maximum contraction recorded for the three catches of a basketball.

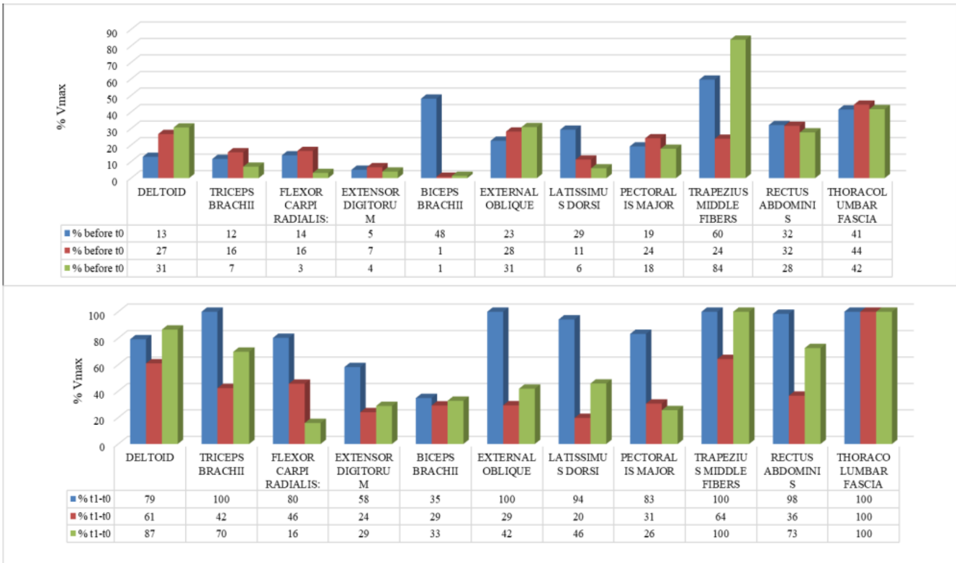

Figure 7. Percentage of maximum contraction recorded before t_0 and between t_0 - t_1

Source: figure arising from the original research activity

Conclusion

The results obtained demonstrate that the simple responses such as upper limbs extension can be produced with different neuromuscular patterns when the task was modified.

The coordination in the motor cortex is an important component of voluntary movement because specific anticipatory adjustments of certain postural muscles could provide the stable support needed to successfully complete the intended actions such as catching and throwing a ball as quickly as possible.

To the extent that postural muscle activity precedes and is specific to a given movement, it could be argued that muscle activity is a component of the voluntary response planning.

Regarding the time of information processing, the finding is relevant for improving the motor program because there may be an anticipation of movement even in the joint of the hand or fingers that initiates a motor act before muscle groups of other body segments.

The neuromuscular activity can be a component of a voluntary response which has implications for motor control models of response organization. This sort of feedforward mechanism may control both postural and task response components.

At this stage of learning, a complex motor action, like catching a ball of different sizes and weights, requires a stable connection between the systems involved in the trials, such as hand-eye coordination and telekinetic movement of the upper limbs. There is an anticipatory motor pattern activity in both work task and upper limbs muscles which was examined for catching a ball and may be considered a major component of voluntary bilateral arms extension.

Differences in the dominance of certain structural moment of anticipation related to the fact that the subject of the case study does not practice any sport can be revealed. But this does not mean that there is no representation (scheme or program) that determines certain aspects of the individual internal model according to the level of sports training. Even if it is currently a case study, the analyzes of the surface electromyography (EMG) signals indicate that there is a link between the evolution of anticipation times and the level of psychomotor training in the learning area, as well as the differences in anticipation of time between the catches.

Regarding the subject's age of our research as well as the lack of a training stage in any sport, we can highlight the existence of a weak telekinetic anticipation time, which shows that an internal learning model should be developed and supported from an early age less than 13 years. The participant's ability to use its own neural representation in a motor action requires future investigations of neural mapping during the execution of another motor task, in order to better highlight the mechanism of telekinetic anticipation.

References

Baumann, O. Borra, R. J., Bower, J. M., Cullen, K. E., Habas, C., Ivry, R. B., Leggio, M., Mattingley, J. B., Molinari, M., Moulton, E. A., Paulin, M. A., Pavlova, M. A., Schmahmann J. D., & Sokolov, A. A. (2015). *Consensus Paper: The Role of the Cerebellum in Perceptual Processes, Springer Cerebellum, 14*(2), 197–220. https://doi.org/10.1007/s12311-014-0627-7

Bernstein, N.A. (1967). *The Coordination and Regulation of Movements.* Pergamon Press.

Berthoz, A. (1993). *Multisensory control of movement.* Oxford University Press Inc.

Bongaardt, R., & Meijer, O. G. (2000). Bernstein's Theory of Movement Behavior: Historical Development and Contemporary Relevance. *Journal of Motor Behavior*, *32*, 57-71. https://doi.org/10.1080/00222890009601360

Botezatu, C., Andrei, C., & Hillerin, P. J. (2014). Neuromuscular Aspects of Anticipation in Preparing the Body for the Contact Structure in Motrice Performance. *Sport Science Rewiev Journal,* XXIII(1-2), 1-23. https://doi.org/10.2478/ssr-2014-0001

Brenton, J., & Müller, S. (2018). Is visual-perceptual or motor expertise critical for expert anticipation in sport? *Applied Cognitive Psychology,* 32(6), 739-746. https://doi.org/10.1002/acp.3453

Buckner, R. L., Krienen, F. A., Castellanos, A., Diaz, J. C., & Thomas Yeo, B. T. (2011). The organization of the human cerebellum estimated by intrinsic functional connectivity. *Journal of Neurophysiology,* 106(5), 2322-2345. https://doi.org/10.1152/jn.00339.2011

Dănăilă, L., & Golu, M. (2000). *Tratat de neuropsihologie* [Treatise on Neuropsychology], Vol.I. Editura Medicală.

Delafield-Butt, J. T., & Gangopadhyay, N. (2013). Sensorimotor intentionality: The origins of intentionality in prospective agent action. *Developmental Review*, *33*(4), 399-425. https://doi.org/10.1016/j.dr.2013.09.001

Dima, E. (2007). *Dicționar explicativ ilustrat al limbii române* [Illustrated explanatory dictionary of the Romanian language]. Editura Arc şi Gunivas.

Epuran, M. (2011). *Motricitate și psihism în activitățile corporale* [Motor skills and psychism in bodily activities], Vol. 1. Editura FEST.

Forestier, N. (2018). *Intégration sensorielle - Rôle des signaux centraux* [Sensory integration - Role of central signals.]. Lecture session at the Doctoral School (Material slides 57-58). University of Pitesti.

Gau, R. Bazin, P-L., Trampel, R., Turner, R., & Noppeney, U. (2020). Resolving multisensory ant attentional influences across cortical depth in sensory cortices. *eLife*, 9, e46856. https://doi.org/10.7554/eLife.46856

Hillerin, P. J. (2011). *Aplicații ale fizicii în Educația Fizică și Sport* [Applications of physics in Physical Education and Sports]. Suport de curs, Anul III, Facultatea de Educație Fizică şi Sport, Universitatea din Piteşti.

Hunter, S. K., Ryan, D. L., Ortega, J. D., & Enoka, R. M. (2002). Task differences with the same load torque alter the endurance time of submaximal fatiguing contractions in humans. *Journal of Neurophysiology*, *88*(6), 3087–3096. https://doi.org/10.1152/jn.00232.2002

Kandel, E.R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth A. J. (2013). *Principles of Neural Science* (5th edition). The McGraw-Hill Companies, Inc.

Macovei, S., & Hillerin, P. J. (1997). Orientation de la préparation physique et technique au moyen d'un test du train inférieur. *Les Cahiers de l'INSEP*, *18-19*, 267-271. https://doi.org/10.3406/insep.1997.1274

Marin, C. De Hillerin, P. J., Marin M., & Vizitiu, C. (2015). Arguments for a unified psycho-neuro-motor approach in Human Performance training. *Palestrica of the third millennium – Civilization and Sport Journal* 16(2), 107–112. http://www.pm3.ro/pdf/60/ro/08%20-%20marin%20%20%20107-112.pdf

Ohashi, J. (1997). The effects of preceded fatiguing on the relations between monopolar surface electromyogram and fatigue sensation. *Applied human science: journal of physiological anthropology, 16*(1), 19-27. https://doi.org/10.2114/jpa.16.19

Pailhours, J., & Bonnard, M. (1999). Programme moteur; Mouvement; Les mouvements volontaires. In Larousse (Ed.), Grand Dictionnaire de la Psychologie. Larousse .

Sbenghe, T. (2002). *Kinesiologie - Știința mișcării* [Kinesiology-The science of movements]. Editura Medicală.

Soltani, P., & Vilas-Boas, J. P. (2016). Muscle activation during exergame playing. In D. Novák, B. Tulu, & H. Brendryen (Eds.), Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice (pp. 312-341). IGI Global. https://doi.org/10.4018/978-1-4666-9522-1.ch015

Williams, D. F. (2006). *Dicționar de biomateriale* [Dictionary of biomaterials]. Editura Casa Cărții de Știință.

World Health Organization. (2020). Coronavirus disease (COVID-19) advice for the public. *World Health Organization* [Updated on 2020 October 13]. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public