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VARIANTS OF UPPER LIMB MOTION INDEX CALCULATIONS IN THE ASSESSMENT OF UPPER LIMB MOTION DYSFUNCTION

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Abstract: *The use of objective human diagnostics methods when identifying motion dysfunctions often comes down to the use of various types of scales or indexes facilitating the analysis of large amounts of kinematic data recorded during the performance of movements. An example of an index dedicated for assessing upper limb motion dysfunction can be the ULMDI (Upper Limb Motion Deviation Index) referred to in this study. The research aimed to identify the effect of different UMLDI variants, allowing for various numbers of repeated upper limb movements as well as with and without consideration of mobility measurements related to the sternoclavicular joint, on the obtained index values. The research also involved the assessment of motion dysfunction (based on different ULMDI calculation variants) related to individual patients and comparing it with the assessment performed by the physiotherapist. The research-related tests involved 23 healthy subjects constituting the reference group and 3 patients for whom different ULMDI variants were calculated. The analyses resulted in the determination of the effect of various quantities taken into consideration when calculating the above-named index on the value of the ULMDI in relation to patients subjected to the tests.*

Keywords: ULMDI, Upper limb dysfunction, Indexes, Diagnosis.

1. Introduction

The use of objective human diagnostics methods when identifying motion dysfunctions often comes down to the use of various types of scales or indexes. The use of related scales makes it possible to classify patients of various disability levels in groups characterized by similar motor abilities (Gzik, 2016). As regards the assessment of upper limb motor dysfunction it is possible to distinguish indexes enabling the quantitative comparison of the shapes of anatomic angle courses in joints in relation to specific activities and in relation to patients with courses determined on the basis of the motoric model based on healthy individuals. An exemplary index could be the RMS (Root Mean Square distance) used in tests (Jaspers, 2011) and (Butler, 2012), which, in a quantitative manner, identifies the area between the patient-related course and the model course. It is also possible to use the PULMI (Paediatric Upper Limb Motion Index) (Butler, 2012) expressing, in a numerical manner, the mean "distance" between the course of angular quantities in joints in relation to patients and the identified motion model referred to the standard deviation of the entire study group. When applying the PULMI it seems justified to use the supplementary SDDI (Standard Deviation of Differential Index), the algorithm of which is based on the same measured quantities as the PULMI, yet it enables the identification of other features of angular

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courses. The above-named index supplements the PULMI by assessing the manner of motion performance.

Measured kinematic quantities, i.e. the time values of anatomical angles in the upper limb joints, constitute the basis of the ULMDI (Upper Limb Motion Deviation Index) (Jurkojc, 2017) developed for the purposes of previously performed tests. The ULMDI algorithm comes from the algorithm of calculations enabling the biometric identification of faces on the basis of the SVD matrix distribution. The above-named algorithm is also used in gait analysis when calculating the GDI (Schwartz, 2008) using 9 courses of kinematic quantities in time to identify the patient's level of disability. On the basis of calculations of kinematic quantities used in the algorithm, including, the number of group members and the number of repetitions performed by individual persons, it is possible to take into consideration different ULMDI variants. The question which arises is whether, similar to the GDI, the algorithm of the ULMDI calculations should include 9 courses of kinematic quantities which, in relation to the upper limb, could constitute the time values of anatomic angles in the sternoclavicular, carpal, cubital and humeral joint, or whether, similar to the PULMI, should include fewer of the above-presented courses. In the case under consideration it is also worth considering how much the values of the ULMDI will change without taking into consideration the trunk mobility in the area of the sternoclavicular joint.

The research-related tests aimed to determine the effect of the different variants of the UMLDI taking into account the number of repetitions of movements performed by the upper limb as well as taking and not taking into account mobility measurements in the sternoclavicular joint area on the obtained index values. The subsequent stage also involved the assessment of motion dysfunction (based on different ULMDI calculation variants) related to individual patients and comparing it with the assessment performed by the physiotherapist.

2. Methods

Participants: The tests involved 23 healthy individuals (10 females and 13 males (aged 23.35 SD 1.37)) and 3 patients with motion dysfunctions in the area of upper limbs (aged p1:17, p2:15, p3:41). The motion dysfunction of patient p1 included damage to peripheral nerves in the left limb through mechanical trauma. The patient had difficulty performing movements in the area of the left cubital and carpal joint. The motion dysfunction of patient p2 included motion anomalies in the area of both limbs; the patient suffered from the spasticity of both limbs caused by infantile cerebral palsy. Patient p3 suffered from damage to the upper part of the brachial plexus responsible for difficulty in moving the left limb.

Selected pattern motions: The patients performed a motion sequence related to the tasks of gross graphomotor ability performed within daily clinical therapy. The motion sequence consisted in lifting the upper limbs and lowering them in the manner presented in Fig. 1. The sequence started with position a) followed by the movement to position c) followed by a short pause, after which the movement from position c) reached position e).

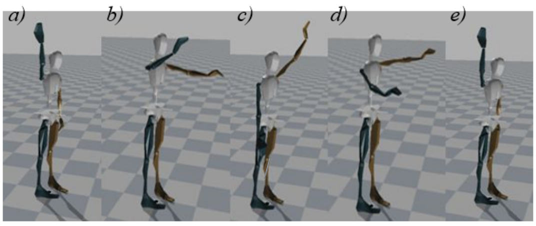

Fig. 1. Motion sequence.

Data collection: The collection of kinematic data included the recording of three repetitions of performed actions using the motion analysis systems provided with the MVNBiomech inert sensors manufactured by Xsens. The collected data included the course of anatomic angle values in the sternoclavicular, humeral, cubital and carpal joints.

Calculations: The quantities recorded during the tests were uploaded to the Matlab software programme for further analysis. The algorithm discussed in the publication by Jurkojc (2017) was used to calculate the values of the ULMDI in relation to the entire motion (from position a to position e). The primary version input data included the following 9 kinematic quantities recorded in the upper limb area:

- flexion/ extension of the upper section of the trunk around the sternoclavicular joint,
- the rotation of the upper section of the trunk around the sternoclavicular joint,
- abduction / adduction at the glenohumeral joint,
- rotation in the glenohumeral joint,
- flexion/ extension the glenohumeral joint,
- pronation / supination of the elbow joint,
- flexion/ extension of the elbow joint,
- elbow adduction / radial abduction of the wrist joint,
- palmar / dorsal flexion of the wrist joint.

W The first stage involved the collection of data concerning 23 healthy individuals and 3 patients in one matrix, which, at the subsequent stage, was subjected to the SVD decomposition with the retaining of the unitary lengths of single vectors and single values. The following step consisted in the calculations of appropriate data contiguity indexes and their mean values. The final stage included the calculation of the raw index value, which afterwards was normalised in relation to the mean value and the standard deviation calculated for the group of healthy individuals. The calculated UMDI value measured the "distance" between the tested upper limb movement of the person having motion difficulties and the pattern adopted for the healthy individuals. The above-named value should be calculated independently for each upper limb. This quantity can be interpreted by stating that when the UMDI is close to 100 or higher, the motion sequence of a given person is closer to the adopted pattern and motion pathology does not take place. A repetitive decrease in the UMDI by 10 below 100 depicts one standard deviation from the adopted TD pattern.

The test-related calculations took into consideration all recorded movements, i.e. three repetitions stand for so-called group 1, one repetition related to each person stands for so-called group 2. The test-related calculations also took into account 2 versions of the index calculations, i.e. ULMDI9 including 9 courses of anatomic angles and calculated in accordance with the algorithm described by Jurkojc (2017) and ULMDI7 not including movements in the sternoclavicular joint.

3. Results

The test results concerning different ULMDI variants are presented in Tab**.** 1. In Tab. 1 colours were used to designate threshold values including the linear change in the colour gradient between them.

Tab. 1: Values of the ULMDI calculations, green colour designates values above 90, whereas red colour designates values below 70.

			Group of healthy people		p1	p2	p3
			Mean	SD			
GROUP 1	Left limb	$ULMDI_7$	100	10	75.57	77.77	77.29
		$ULMDI_9$	100	10	74.53	76.31	76.53
	Right limb	$ULMDI_7$	100	10	90.70	73.33	90.43
		$ULMDI_9$	100	10	90.75	72.18	90.37
GROUP 2	Left limb	$ULMDI_7$	100	10	81.63	75.96	79.55
		$ULMDI_9$	100	10	80.52	74.29	78.65
	Right limb	$ULMDI_7$	100	10	92.09	67.68	88.57
		$ULMDI_9$	100	10	91.93	66.57	88.64

4. Discussion

The ULMDI coefficients in Tab. 1 correspond to the greater values for the healthy limbs than those concerning limbs with dysfunction in relation to each calculated index value. In terms of the healthy limbs, the value of calculated quantities exceeded 88 points, whereas in relation to the limbs with motion dysfunction, the related values were even below 70 points. The colours assigned to the individual values in Tab. 1 related to the ULMDI coefficients enable the identification of the limb with dysfunction and the healthy limb. In terms of the first patient (p1) and their right (healthy) limb the value of the ULMDI coefficients were higher by approximately 10 points. In Tab. 1, the aforesaid values are marked green. The values related to the limb with motion dysfunction are marked red and orange. As regards the first patient (p1), the above-presented coloring enables an easy indication of the healthy limb and the limb having motion dysfunction. A slightly different situation is that concerning the second patient (p2), where low values of the ULMDI coefficients (in red) for the right limb and only slightly higher for the left limb were observed. In terms of the third patient (p3), the results explicitly indicate the presence of motion dysfunction in the left limb. In addition, the left limb of the third patient (p3) was clinically diagnosed as being disabled.

To identify the effect of the different variants of the calculated indexes (7 and 9) and to take into account the two groups of the tested courses it was necessary to perform the comparative analysis of the results obtained in the tests. The first stage involved the comparison of values obtained for variants 7 and 9 of the calculated indexes. The data contained in Tab. 1 justify the conclusion that the ULMDI7 and the ULMDI9 adopted, roughly, the same value in relation to the same group and limb, with differences usually not exceeding 2 points in the adopted scale. Taking into consideration the sternoclavicular joint increased the differences between the values concerning the healthy limb and that with the motion dysfunction.

Greater differences were obtained in relation to the comparative analysis of the index-related results with the division of the courses included in the calculations into groups (group 1 and group 2). The increase in the number of the courses when calculating the indexes also resulted in the increase in the difference between the values obtained for the healthy limbs and the limbs with the motion dysfunction. In some cases, the above-named differences changed from 10 points to even 14 points in the adopted scale. In addition, the above-presented manner of the calculation of the indexes led to the change in the background coloring determined on the basis of the value related to patient 1 and in the case of the left limb from orange to yellow, possibly implying the lower level of motion dysfunction.

5. Conclusions

The index-based analysis led to the obtainment of the objective method enabling the assessment of a disability degree based on the trajectory of angles in relation to the upper limb joints. The analysis, in the quantitative manner, identified the degree of disability by comparing the results obtained in the tests with those of the assumed model. Each value-based variant of the index properly indicated the limb with a greater motion dysfunction. Taking the sternoclavicular joint into consideration increased the difference between the healthy limb and the limb with the dysfunction by approximately 2 points in the adopted scale, which facilitated the detection of the limb with dysfunction. Similar conclusions were reached on the basis of the analysis of different variants of the index in relation to three repetitions performed by each of the persons. The difference between the indexes calculated for the various number of repetitions was greater and reached between 4 and 12 points in the adopted scale. When performing analyses enabling the assessment of motion dysfunction using the ULMDI, it is important to take into account a greater number of recorded courses and measurements in the sternoclavicular joint.

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