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MOTION ANALYSIS PROTOCOL FOR THE CLINICAL EVALUATION OF PLAYING-RELATED MUSCULOSKELETAL DISORDERS IN VIOLINISTS, VIOLISTS, AND CELLISTS

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INTRODUCTION





BACKGROUND

- **RefLabPerform:** "**Ref**erence **lab**oratory for the evaluation of neuromusculoskeletal diseases in **perform**ing artists" at "**INAP/O** *Institute for Applied Physiotherapy and Osteopathy*" in Osnabrück, Germany
 - > Integration of advanced instrumented biomechanical analysis into musicians' physiotherapy
- Novel marker-based method for analyzing 3D upper body kinematics of violinists and violists (and cellists)
 - > Multi-segmented shoulder and spine models while providing a simple application
 - > Good compromise between accuracy, repeatability and practicability for clinical application
 - > Guides clinicians to improvements in injury prevention, diagnosis and treatment
- Recent studies about **clinical feasibility** and **reproducibility** of the method:
 - Wolf E, Möller D, Ballenberger N, Morisse K, Zalpour C. Marker-Based Method for Analyzing the Three-Dimensional Upper Body
 Kinematics of Violinists and Violists: Development and Clinical Feasibility. Med Probl Perform Art. 2019 Dec 1;34(4):179–190.
 - Wolf E, Möller D, Ballenberger N, Morisse K, Zalpour C. Marker-Based Method for Analyzing the Three-Dimensional Upper Body Kinematics of Violinists and Violists: Reproducibility. Med Probl Perform Art. 2019 Dec 1;34(4):179–190. Accepted.



PURPOSE

Development and application of a motion analysis protocol for the *kinematic* and *muscular* evaluation of functional upper body movements of high and low string players in a clinical setting for the investigation of playing-related musculoskeletal disorders (PRMDs).





DEVELOPMENT & APPLICATION





APPROACH

- Integration of motion analysis into the physiotherapeutic clinical reasoning process for...
 - > Testing clinical (working) hypotheses
 - > Evaluating treatment outcomes (pre-/post-interventional comparison)
- Development largely based on *"A framework for the definition of standardized protocols for measuring upper-extremity kinematics"* by Kontaxis et al. (2009); adapted by Cutti et al. (2018)



DEVELOPMENT





DEVELOPMENT

• Clinical question:

Which intra-individual body postures and loads are related to neuromusculoskeletal demands in the upper body of a string player?

- Six *basic* upper-body symptom regions (S1-6):
 - S1-3: Cervical, thoracic, or lumbar spine (upper & lower back, head/neck, shoulders)
 - S4: Cervical-shoulder-arm (head/neck, upper back, shoulders, upper & lower arms, hands)
 - S5: (Left/right) Arm proximal (shoulder, upper & lower arm)
 - S6: (Left/right) Arm distal (shoulder, upper & lower arm, hand)
- Measurement parameters:
 - Kinematic and muscular parameters of upper body segments, joints and muscles
 - > Relative segment/joint rotation angles as well as muscle activities over time



DEVELOPMENT

- 14 upper-body segments
 - Pelvis, lumbar, lower & upper thoracic spine, head, thorax, scapula, humerus, forearm (radius/ulna)
- 18 upper-body muscles
 - M. erector spinae (pars lumbalis/thoracalis)
 - M. sternocleidomastoideus
 - M. scalenus anterior
 - M. serratus anterior
 - M. trapezius (pars ascendens/descendens)
 - M. deltoideus (pars clavicularis/acromialis/spinalis)
 - M. pectoralis major (clavicularis/sternocostalis)
 - M. triceps brachii
 - M. biceps brachii
 - M. flexor/extensor carpi ulnaris/radialis

UTS = Upper thoracic spine LTS = Lower thoracic spine HT = Humerothoracic ST = Scapulothoracic GH = Glenohumeral





APPLICATION







CASE STUDY





SUBJECT

Experienced female classical violinist, student and orchestra musician

- Age: 18 years; Experience: 13 years playing
- *Practice*: 2-3 hours per day, 7 days per week, breaks as needed
- Change of playing style at age of 13, because of too much pressure in left-hand fingers
 Problem (PRMD)
- Neck-related arm pain over the last 4 years without any causing event

Subjective findings (anamnesis)

- Pain occurred after 30 minutes of playing
 - Intensity was influenced by tempo and complexity of musical piece (up to 8/10 VAS)
- No red or yellow flags were present

03 CASE STUDY



SUBJECT

Body chart





SUBJECT

Objective findings (physical examination)

> Cervical range of motion measured with a digital goniometer:

Extension	60° op 1	
Flexion	61°	
Lateral flexion	right	left
	46° op P left	36° op 1
Rotation	right	left
	83° op P left	77° op 1

- Upper Limb Neural Tension Test 1: Outward rotation of the shoulder caused pain no. 4
- Strength test:
 - Left serratus anterior muscle caused pain no. 3 and 4
 - Lower trapezius muscles seemed weak
- > Forearm muscles were sensitive to pressure



HYPOTHESIS & PREPARATION

Working hypothesis

- Neck-related arm pain with neurodynamic component
- Motor control problem in the scapulothoracic region

Symptom area

> S4 (*left*) (Cervical-shoulder-arm area)

Segments/Joints

- > UTS, LTS, head and thorax; left scapula, humerus, forearm, and hand
- > UTS/LTS and neck joint; left HT, ST, GH, elbow, radioulnar, and wrist joints

Muscles

Left sternocleidomastoid, serratus, upper & lower trapezius, deltoid muscle (anterior), and forearm flexors & extensors

UTS = Upper thoracic spine LTS = Lower thoracic spine HT = Humerothoracic ST = Scapulothoracic GH = Glenohumeral



DATA COLLECTION

Marker set and surface electrodes







CAST = Calibrated Anatomical Systems Technique GH-JRC = Glenohumeral Joint Rotation Center

bpm = Beats per Minute

DATA COLLECTION

Movement trials

Instruments: Qualisys 3D Motion Capture System (16 cameras) and Noraxon Ultium EMG System

- Static calibration trial (CAST) 90° elbow flexion; left forearm supinated & right forearm pronated
- 2. Functional calibration trials GH-JRC, elbow & pro-/supination axes estimation
- Functional assessment trials
 Chromatic scale (C major):
 50 bpm; 100 bpm; 120 bpm

Processing & extraction: Visual 3D (C-Motion)



Joint angles | Minimum, Maximum & Range of Motion | Differences between trials (Activities 1-3)





Joint angles | Minimum, Maximum & Range of Motion | Differences between trials (Activities 1-3)



Left glenohumeral joint



Joint angles | Minimum, Maximum & Range of Motion | Differences between trials (Activities 1-3)



Left elbow joint



Left wrist joint



Mean muscle activity | Differences between trials (Activities 1-3)





Mean muscle activity | Differences between trials (Activities 1-3)





Mean muscle activity | Differences between trials (Activities 1-3)





Muscle activity | %-Input of each muscle | Differences between trials (Activities 1-3)





IMPLICATIONS | PRE-ASSESSMENT

- Pain occurred at end of second and beginning of third functional trials
- Greater tempo and pain appeared to have an impact on left-sided joint angles and muscle activity levels
 - > Less movement and range of motion
 - > Less muscle activity in forearm muscles
 - > More %-input activity in scapulothoracic muscles
- ✓ Working hypothesis "Motor control problem in the scapulothoracic region" VERIFIED.



TREATMENT PROTOCOL

Interventions (four appointments over one week; each with time frame of 30-60 min)

- 1. Manual therapy
 - Mobilization techniques in cervical and thoracic spine as well as first rib on the left side
 - *Mobilization of nervous system* with slider techniques in the *left arm*
- 2. Training
 - Specific *strengthening exercise*
 - Motor control exercise for the scapulothoracic region
- 3. Education
 - Load management



Joint angles | Minimum, Maximum & Range of Motion | Pre-/post-comparison (Activities 1-3)





Joint angles | Minimum, Maximum & Range of Motion | Pre-/post-comparison (Activities 1-3)



Left glenohumeral joint



Left elbow joint

Joint angles | Minimum, Maximum & Range of Motion | Pre-/post-comparison (Activities 1-3)



MIN | PRE MAX | PRE ROM | PRE



Mean muscle activity | Pre-/post-comparison (Activities 1-3)



Left lower trapezius

Left upper trapezius



Mean muscle activity | Pre-/post-comparison (Activities 1-3)



Left deltoid anterior

Left serratus anterior



Mean muscle activity | Pre-/post-comparison (Activities 1-3)



Left forearm flexors

Left forearm extensors



Muscle activity | %-Input of each muscle | Pre-/post-comparison (Activities 1-3)





IMPLICATIONS | POST-ASSESSMENT

Pre-/post-interventional comparison showed changes in motor program

- > Noticeable higher mean activation in upper trapezius and deltoid while less in the remaining muscles
- > Only marginal differences in joints' ranges of motion and muscles' activity inputs between tempi
- > Playing style appeared to be more stable/did not differ between tempi compared to pre-analysis
- ✓ Nearly the same motor program for each tempo





CLINICAL IMPLICATIONS & FUTURE WORK





CLINICAL IMPLICATIONS

- Intra-individual evaluations of simultaneously joint and muscular function in high and low string players during clinical consultation
- ✓ Deeper insights into the dynamic motor function and load while playing
- Contribution to the diagnosis of PRMDS in terms of an objective, comprehensive and yet clinically feasible diagnostic assessment
- ✓ Evaluation of *pre-post-interventional* outcome/treatment
- 4 CAUTION! Be careful with clinical decision making!
- bata/results are subject to both intra-individual variations and measurement errors
- 4 Smallest *clinically relevant changes* are not clear/were *not determined* yet
- 4 Results should be interpreted together with other *clinical findings only* (e.g., physical examination)



FUTURE WORK

- Integration into *clinical reasoning process* and test of overall *physiotherapeutic workflow*
- Adapting to further instrumental groups
 - Piano, Trombone and Drums
 - > Evaluation is mandatory!
- Evaluation of IMU vs. marker-based
- Evaluation of outcome parameters and their visualization forms
- Identification of standard values/thresholds





THANK YOU FOR YOUR ATTENTION.

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