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# MARKER-BASED METHOD FOR ANALYZING THE THREE-DIMENSIONAL UPPER BODY KINEMATICS OF VIOLINISTS AND VIOLISTS

## DEVELOPMENT AND CLINICAL FEASIBILITY

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# INTRODUCTION

# BACKGROUND

ISB = International Society of Biomechanics
JCS = Joint Coordinate System
AL = Anatomical Landmark

- **3D motion analysis** has proved **helpful** in the **diagnosis** of different **musculoskeletal syndromes** in high string players and **identifying** injurious movement **patterns** (Schemmann et. al, 2018)
- **Optoelectronic** 3D motion capture system allows an **accurate** and **objective** assessment of **posture** and **motion** during **violin and viola performance** (Shan et al., 2004, Shan et al., 2007; Rabuffetti, 2007; Visentin, 2015)
- **Reference upper body model** and **more physiological shoulder model,** that separates the joints of the shoulder complex, has **not been proposed** for high string players as yet
- **Scapula** cannot be disregarded when evaluating **musculoskeletal strain** in the **shoulder**
- **ISB** recommends **JCSs** using **ALs** as **reference** for the **placement** of surface **markers** (Wu et al., 2005)
- **Skin markers** are **inappropriate** for some of the **proposed locations** during **violin or viola playing**
  - **Skin movement** artifacts (e.g. movement of the scapula underneath the skin)
  - Some **markers interfere** with the **instrument** on the shoulder
  - **Bowing arm** in motion might **occlude** markers on the **sternum** and **right forearm**

# AIM(S)

Development of a marker-based method for quantifying 3D upper body kinematics of high string players and to demonstrate its clinical feasibility in violin and viola performance.

- Provide an **objective evaluation** of **high string players' motor strategies**, especially in the **shoulder complex**, while **minimizing skin movement artifacts**, **marker occlusions** and **limitations in instrument placement**.

- ***Repeatable*** *as well as* ***independent*** *of the* ***optoelectronic motion capture system*** *and* ***laboratory site***
  ➔ Will be subject to further investigation.

# MATERIALS AND METHODS

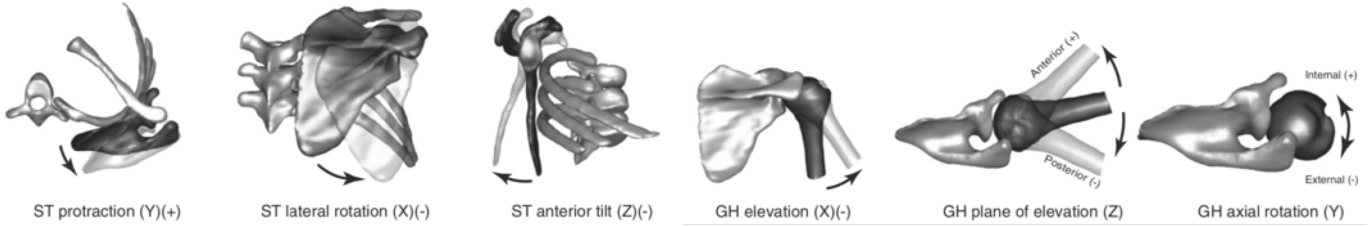
# BIOMECHANICAL MODEL

16 segments in total:

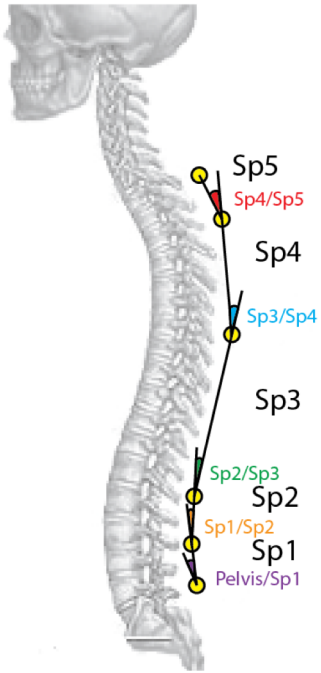
- Pelvis, thorax, spine (5-link-model) and head
- Left and right upper limbs: scapula, upper arm, forearm and hand

15 joints in total:

- Pelvis/Thorax and neck
- Spinal “joints” (Pelvis/Sp1, Sp1/Sp2, Sp2/Sp3, Sp3/Sp4, Sp4/Sp5)
- Scapulothoracic (ST), glenohumeral (GH), elbow and wrist joints




(Brochard et al., 2012)




(Leardini et al., 2011)

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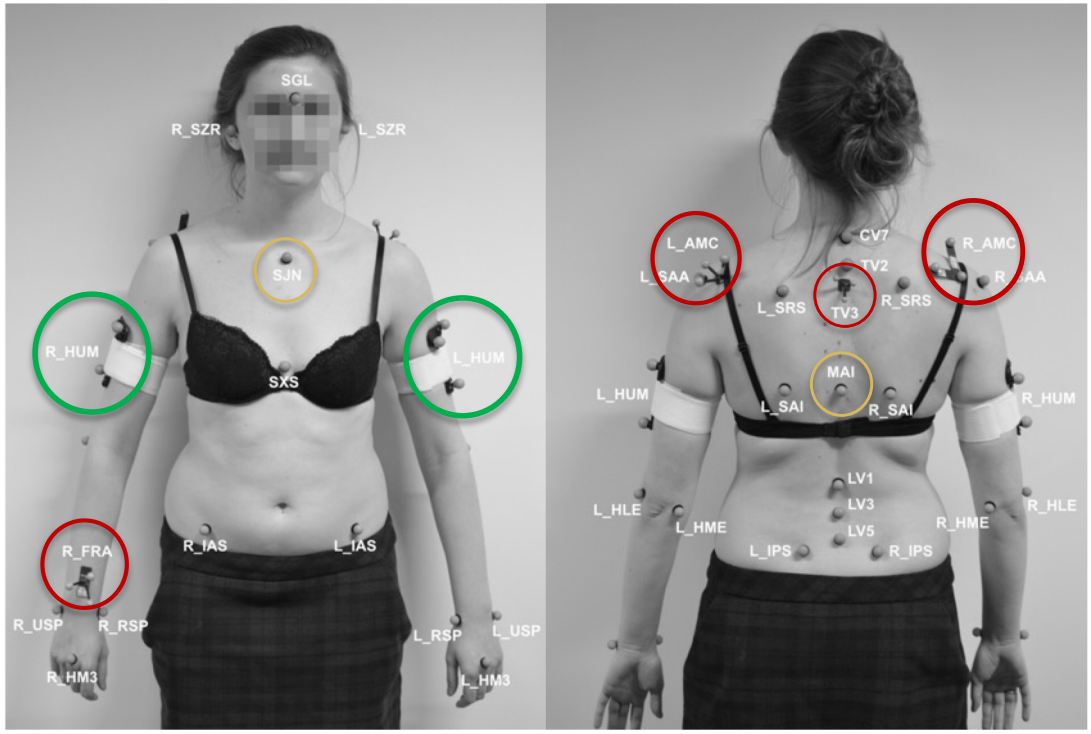
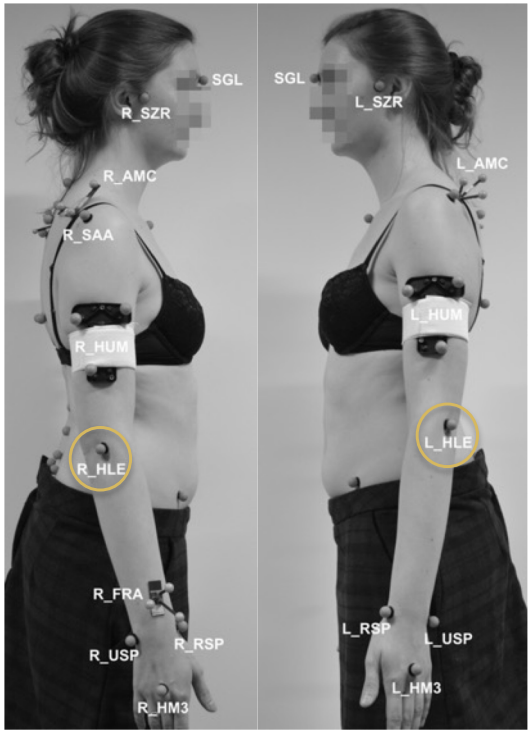
# MARKER SET

AMC = Acromion Marker Cluster
TV3 = 3rd thoracic vertebra

- Retro-reflective, spherical markers (Ø: 14 mm): 31 for calibration and 21 for tracking
- Two pre-built (upper arms) and four custom-made (AMC, TV3, right forearm) rigid marker clusters



# PARTICIPANTS

- Twelve experienced violinists
- No history of musculoskeletal or neurological problems
- Approved by local Ethics Committee

| Gender (♂, ♀) | Age (years) | Years playing (years) | Height (cm) | Weight (kg) |
|---|---|---|---|---|
| ♂ = 2, ♀ = 10 | 22.4 (±2.9) | 15.6 (±2.3) | 170.5 (±8.7) | 61.8 (±7.1) |

# DATA COLLECTION

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

## Static trial

Calibration (CAST)

90° elbow flexion; forearms pronated

(Wu et al., 2005)

## Functional trial

GH-JRC Estimation

5 x 20-30° Flex./Ext., Abb./Add., Circ.

(Lempereur et al., 2010)

## Dynamic trial

Bowing

G# & A on G-string; E & F on D-string; Up-to down-bow; 50 bpm; std. instrument

# STATISTICAL ANALYSIS

## Clinical feasibility

*Ability to* ***quantify*** *upper body* ***kinematics*** *in violin and viola performance* ***detecting*** *even* ***small changes*** *in the motion patterns between two adjacent strings in order to* ***obtain clinically*** *meaningful* ***information****.*

## Analysis

- **Upper body motion patterns:** angle-time graphs, minimum, maximum and range of angular motion were averaged across participants for each string and rotation
- **Inter-subject variability:** SD at each time sample between participants for each rotation and for both the G- and the D-string averaged over sequences
- **Differences between G- and D-string playing:** Random effect models and classification in *large* (> 2/3 of seq.), *moderate* (> 1/3 of seq.), *low* (< 1/3 of seq.) and *no* effects
- All statistical analyses were performed with **R software package** (R Development Core Team, 2014)

# RESULTS

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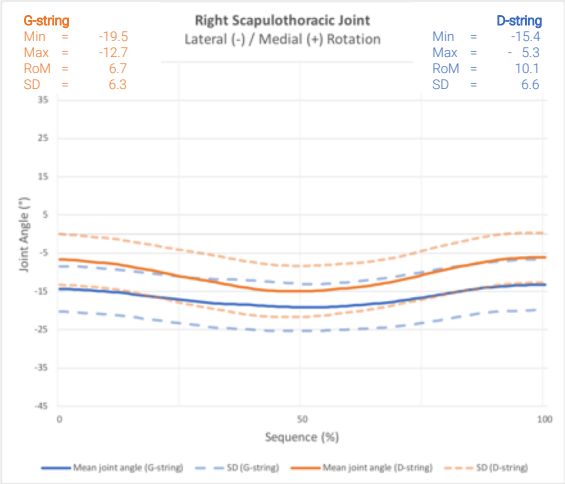
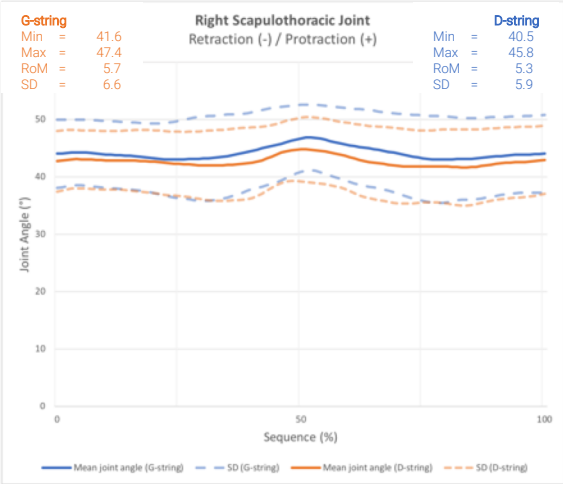
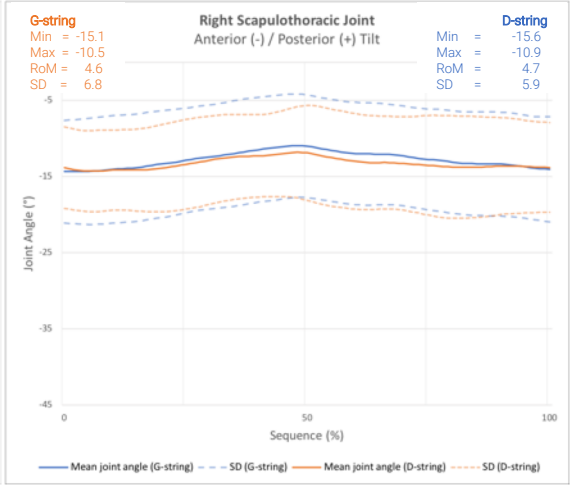
# UPPER BODY MOTION PATTERNS

RoM = Range of Motion
GH = Glenohumeral



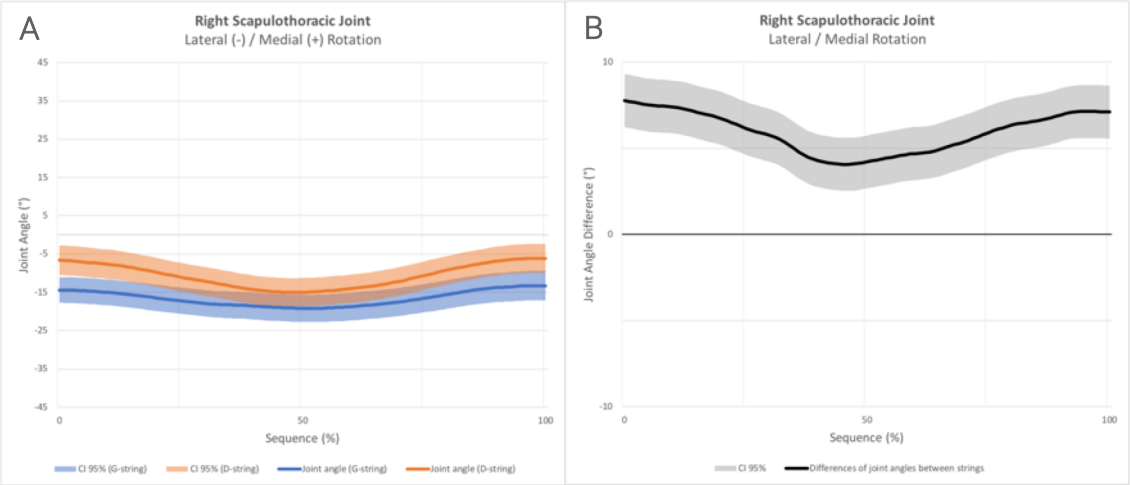




- High **RoM** (> 10°): right **GH**, **elbow** and **wrist** joint rotations
  - ➢ **Spine**, **thorax**, **neck**, and **left upper limb** were quite **static**, while **large** motion occurred in the **right upper limb**
- High inter-subject **variability** (> 10°): left/right **GH plane of elevation**, left **GH in-/external rotation** and left/right **wrist pro-/supination**
  - ➢ **Most** rotation **angles** showed a **reasonable** variability **except** for **GH** and **wrist joints**

# DIFFERENCES BETWEEN STRINGS

ST = Scapulothoracic
GH = Glenohumeral




(A) **Mean joint rotation angles** of G- and D-string bowing including the corresponding confidence interval (CI 95%)

(B) **Mean differences** between G-string and D-string bowing including the corresponding confidence interval
Statistical significance is given when **confidence interval does not intersect with the zero line** ($p < .05$)

- **Significant differences** in the rotation angles **between strings**
- **Strongest effects: left wrist** as well as **right ST** and **GH joints**

# DISCUSSION

# DISCUSSION

- First study using 3D analysis to explore the upper body kinematics of high string players during performance, providing a detailed view of the motor control in the shoulder as well as in the spine
  - Biggest advantage is the more **physiological shoulder and spine models** while providing a **simple application**
  - **Consistent motion patterns** across participants, which agree with the description of fundamental performance techniques in the literature (Galamian., 2013), and **sensitive to differences between adjacent strings**
  - **Good compromise** between **accuracy** and **practicability** for clinical application in violin and viola performance
- But the method has some limitations…
  - **Reliability** and **interpretability** largely **depend** on the **precision** and **accuracy** of the **palpation** procedure, the degree of **skin movement**, as well as **differences** in **systems** and **marker placement** between and within examiners
  - **AMC accuracy decreases** with thoraco-humeral **elevation above 90°** (Lempereur., 2014)
- Since there is no gold standard, we were only able to assess face validity/clinical feasibility

# CONCLUSION AND FUTURE WORK

# CONCLUSION

- ✓ Comprehensive analysis of 3D upper body kinematics of high string players during performance
- ✓ Results suggest that the proposed method is a valid tool for quantifying upper body movements while considering conditions specific to violin and viola playing

- ➢ Multi-segmented shoulder and spine models improve **understanding of the motor strategies** adopted by high string players
- ➢ Knowledge may guide clinicians to **improvements in injury prevention, diagnosis and treatment**
- ➢ Sound base for the implementation of a **complete clinical measurement procedure**

# FUTURE WORK

PRMD = Playing-related Musculoskeletal Disorders

- **Reliability** and **portability** of the method will be subject to **further investigation**.
- Using method for **differences** between **PRMD** and **non-PRMD** musicians
- **Adapting** method to **cello application**

# THANK YOU FOR YOUR ATTENTION.

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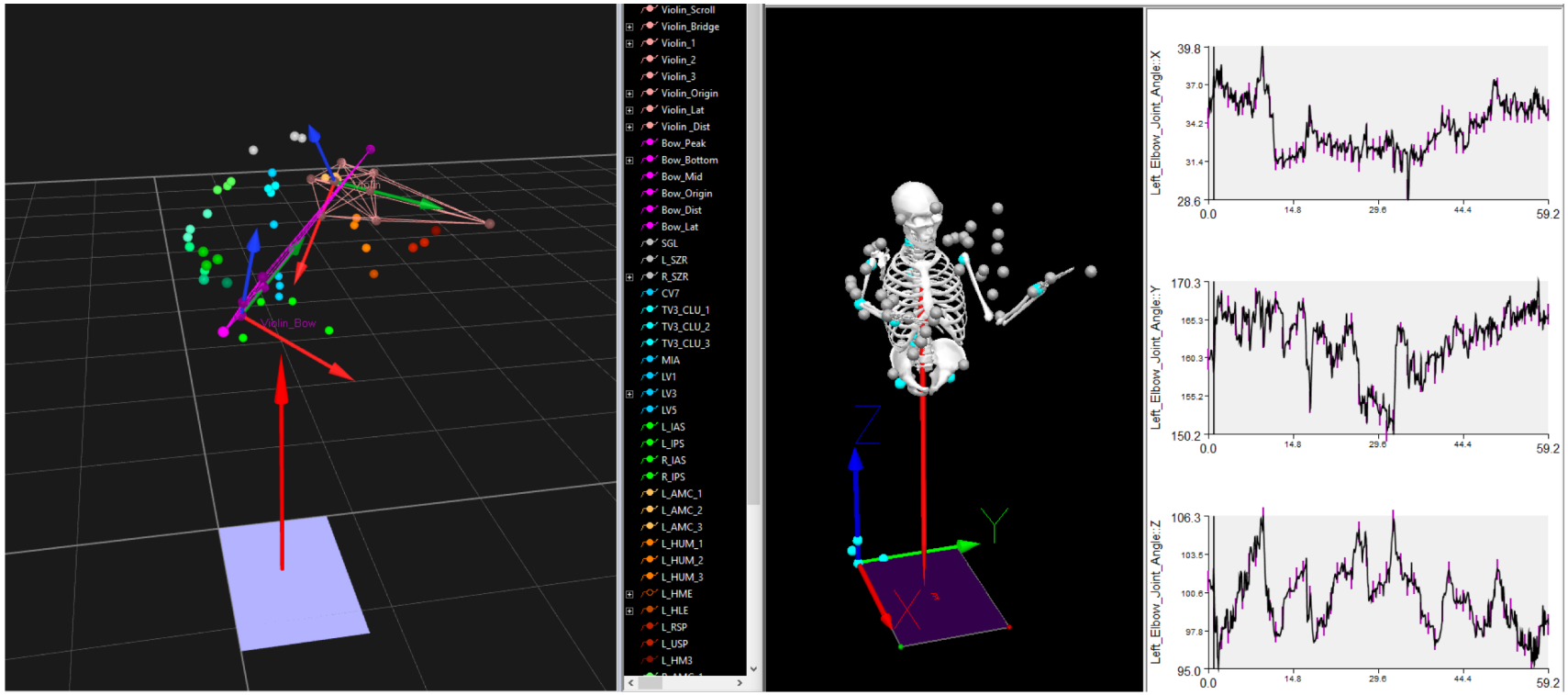

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