Upper Arm Skin Marker Displacement Analysis Using Proximal Ulna Tracking

Lorenzo De Sanctis[1,2], Umile Giuseppe Longo[1,2], Arianna Carnevale[1], Lawrence Gulotta[3], Emiliano Schena[1,4], Andreas Kontaxis[5]
[1]Fondazione Policlinico Universitario Campus Bio-Medico, Via Álvaro del Portillo, 200, 00128 Rome, Italy
[2]Research Unit of Orthopaedic and Trauma Surgery, Department of Medicine and Surgery, Università Campus Bio-Medico di Roma, Via Álvaro del Portillo, 21, 00128 Rome, Italy
[3]Department of Sports Medicine and Shoulder Surgery, Hospital for Special Surgery, New York, NY, USA
[4]Laboratory of Measurement and Biomedical Instrumentation, Department of Engineering, Università Campus Bio-Medico di Roma, Via Álvaro del Portillo, 21, 00128 Rome, Italy
[5]Leon Root Motion Analysis Laboratory, Rehabilitation Department, Hospital for Special Surgery, New York, NY, USA

Summary

This study examined the effects of soft tissue artifact (STA) on the displacement of upper arm markers during dynamic tasks taking a noninvasive tracking protocol as reference. The analysis identified optimal marker placement to minimize STA. Results showed significant estimated STA on the upper arm, with lower displacements observed closer to the elbow and to the axilla region. A complete analysis is provided as no pins were placed in the proximal upper arm region, possibly interfering with the skin motion.

Introduction

Soft tissue artifact (STA) significantly affects the accuracy of joint kinematics, particularly in the shoulder, due to substantial displacements of the skin relative to the underlying bones during movement [1]. Previously, bone pins were used to highlight the challenges of STA in upper arm motion analysis [1]. This study aims to identify regions of marker placement on the upper arm that minimize STA by comparing marker displacements with respect to their predicted positions in the bone-embedded frame (BEF).

Methods

One male volunteer (21 years, BMI: 18.5 kg/m^2, no shoulder pathologies) participated in the study. Markers were placed on all ISB landmarks that were identified with palpation [2]. Additional marker clusters (with 4 markers each) were positioned on the acromion (Fig. 1a) and proximal ulna (Fig. 1b) [3]. The ISB-recommended H1 humeral BEF was tracked using the glenohumeral joint center (from the scapular cluster) and the elbow flexion/extension axis (from the proximal ulna cluster) [2, 4]. Twenty-one 8 mm markers were placed on the upper arm in three groups (posterior, lateral, anterior), starting from the acromioclavicular joint landmark and spaced 4 cm apart in distal direction (Fig. 1c). The participant performed 5 cycles of shoulder forward flexion, abduction-adduction, scaption, horizontal abduction, and three internal/external rotation tasks (from Ski-Pose, then in the sagittal and frontal planes with 90° of shoulder elevation and 90° of elbow flexion), to maximum range of motion. Peak-to-peak displacements of each marker from their expected positions in the BEF were computed using the proximal ulna tracking as ground truth [5]. The expected positions were obtained by applying the instantaneous BEF pose transformation to the static calibration (Ski-Pose) marker configuration. The mean norm of markers displacement across three task sets was considered: the internal/external rotation subset, the nonspecific tasks subset, and all tasks combined.

Results and Discussion

For all tasks, the markers less influenced by STA were L7 (28.38 mm), A3 (30.46 mm), and L6 (31.99 mm). In the int/ext rotation subset, A7 (17.22 mm), A6 (23.09 mm), and L7 (23.12 mm). For the remaining tasks, the markers with the smallest displacements were A3 (31.90 mm), L7 (32.47 mm), and A4 (32.66 mm). When considering markers from different groups, the optimal combination for all tasks included L7 (lateral), A3 (anterior), and P7 (34.23 mm, posterior). For the int/ext rotation subset, A7, L7, and P7 (26.05 mm) were the least affected. In the remaining tasks, the smallest displacements were observed with the combination of A3, L7, and P7 (40.52 mm).

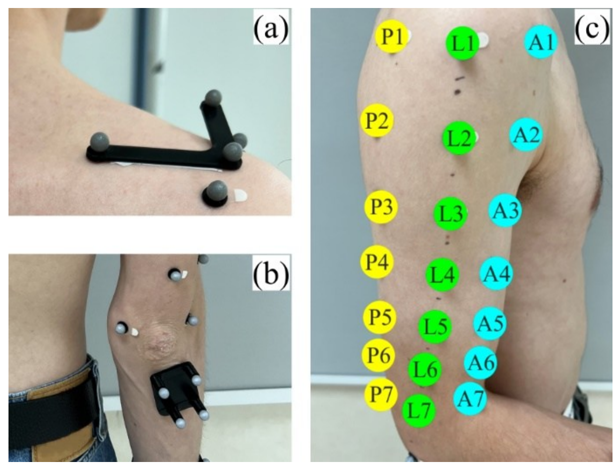

Figure 1: (a) Acromion and (b) proximal ulna marker clusters. (c) Markers location on the upper arm region.

Conclusions

This study identified optimal marker placements to minimize STA on the upper arm when proximal ulna tracking is not available. Future work will expand the sample size to investigate how anthropometric differences may affect these findings and improve their applicability.

References

[1] Blache et al. (2017) *J. Biomech.*, **62**: 39-46
[2] Wu et al. (2005) *J. Biomech.*, **38**: 981-992
[3] Warner et al. (2015) *J. Vis. Exp.*, **96**: e51717
[4] De Sanctis et al. (2025) *J. Biomech*, **185**: 112643
[5] Grimpampi et al. (2014) *IEEE Trans. Biomed. Eng*, **61**: 2