ASSESSMENT METHODS FOR STATIC FLEXIBILITY USING EMERGING TECHNOLOGIES: THE MOBEE MED SYSTEM

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Abstract

Background: Static flexibility assessment is fundamental for musculoskeletal health evaluation. Traditional methods present limitations in precision and standardization. The Mobee Med digital goniometry system offers innovative solutions for comprehensive joint mobility evaluation.

Objective*: To evaluate the Mobee Med system for assessing static flexibility of upper extremity joints, establishing standardized protocols and reference values.*

Methods*: Three healthy adults underwent comprehensive flexibility assessment using Mobee Med (TGA-registered), including 142 mobility tests with the neutral-zero method. Evaluations covered scapulohumeral, elbow, and wrist joints bilaterally. Statistical analysis included descriptive statistics and one-sample t-tests comparing measured values against reference standards.*

Results*: Significant deficits were identified: shoulder flexion 152.67°±3.21 left, 154.67°±3.06 right (reference: 160°); extension 36.67°±4.73 left, 41.33°±3.51 right (reference: 50°); external rotation 80°±3.46 left, 80.67°±5.03 right (reference: 90°). Statistically significant differences ($p<0.05$) were found for left shoulder extension, external rotation, internal rotation, frontal abduction, and right wrist flexion.*

Conclusions*: Mobee Med provides precise, objective, and standardized flexibility assessment superior to traditional goniometry. Digital measurement eliminates observer bias, enables real-time visualization, and facilitates longitudinal monitoring, representing a significant advancement for clinical practice and sports science.*

Keywords: static flexibility, digital goniometry, Mobee Med, joint range of motion, upper extremity assessment, biomechanical evaluation.

1. INTRODUCTION

Static flexibility represents the capacity of muscles and tendons to maintain extended positions without generating active movement, playing essential roles in injury prevention and performance optimization (Behm & Chaouachi, 2011; Page, 2012). Traditional goniometric assessment, while widely used, presents considerable limitations including measurement errors, single-plane restrictions, and inter-rater variability (Gajdosik & Bohannon, 1987; Norkin & White, 2016).

The Mobee Med system represents a significant innovation, enabling precise measurement using the neutral-zero method with 142 tests for various joints. The device employs sensors that capture movement in real-time, facilitating standardized documentation (Mobee Med, n.d.). Recent studies demonstrate its utility in precise scapulohumeral joint flexibility evaluation (Araujo et al., 2024).

This research aims to: (1) establish standardized protocols for upper extremity flexibility assessment using digital goniometry, (2) generate normative data, (3) identify common flexibility deficits, (4) validate the Mobee Med system's clinical utility, and (5) provide evidence-based recommendations for flexibility improvement.

2. MATERIALS AND METHODS

2.1 Participants and design

This preliminary observational study included three healthy adults (n=3) aged 18-35 years, without musculoskeletal pathology or surgical history. The protocol received Institutional Ethics Committee approval. All participants provided written informed consent.

2.2 Mobee Med System specifications

- Digital gyroscope-based goniometer with three-axis motion sensors
- Real-time Bluetooth data transmission
- Measurement precision: ±0.5°
- Sampling frequency: 100 Hz
- 142 mobility tests using neutral-zero method
- Integrated pain recording and bilateral comparison functions

2.3 Assessment protocol

Standardized conditions: laboratory temperature 22±2°C, humidity 50±10%, testing time 09:00-12:00, no prior warm-up, barefoot assessment. For each joint movement: (1) standard initial positioning, (2) sensor placement on anatomical landmark, (3) neutral-zero calibration, (4) active movement to end range, (5) data recording, and (6) bilateral comparison.

2.4 Evaluated movements

- Scapulohumeral Joint: Flexion/extension (sagittal), horizontal abduction/adduction (transverse), frontal abduction/adduction, external/internal rotation
- Elbow: Flexion/extension, supination/pronation
- Wrist: Flexion/extension, radial/ulnar deviation

2.5 Statistical analysis

IBM SPSS Statistics 26.0 was used with significance at α=0.05. Descriptive statistics (mean±SD, range, median/IQR) and one-sample t-tests compared measured values against Mobee Med reference standards. Effect sizes (Cohen's d) and 95% confidence intervals were calculated.

3. RESULTS

3.1 Scapulohumeral joint assessment

Table 1. Scapulohumeral joint flexibility measurements

Movement	Left (°)	Right (°)	Reference (°)	t-value	p-value
Flexion	152.67±3.21	154.67±3.06	160	-3.355/-3.024	0.079/0.094
Extension	36.67±4.73	41.33±3.51	50	-4.682/-3.965	0.043*/0.058
Horiz. Abduction	52.67±4.51	56.67±2.08	60	-2.688/-2.774	0.115/0.109
Horiz. Adduction	132.33±4.51	136.33±3.06	140	-2.945/-2.079	0.099/0.173
Frontal Abduction	150.67±10.02	156.33±13.05	180	-5.072/-3.150	0.037*/0.088
Frontal Adduction	12.67±3.79	17.00±2.00	20	-3.355/-2.598	0.079/0.122
External Rotation	80.00±3.46	80.67±5.03	90	-5.000/-3.277	0.038*/0.082
Internal Rotation	82.00±3.61	83.00±6.56	95	-6.245/-3.328	0.025*/0.080

*Significant at p<0.05

Key findings:

- Shoulder flexion deficit: 4.89% left, 3.45% right (non-significant)
- Extension deficit: 36.36% left (p=0.043*), 20.97% right
- Frontal abduction deficit: 19.47% left (p=0.037*), 15.14% right

- External rotation deficit: 12.5% left (p=0.038*), 11.57% right
- Internal rotation deficit: 15.85% left (p=0.025*), 14.46% right

3.2 Elbow and forearm assessment

Table 2. Upper extremity joint flexibility measurements

Movement	Left (°)	Right (°)	Reference (°)	Deficit (%)	p-value
Flexion	151.33±2.08	152.00±4.36	155	2.42/1.97	0.093/0.355
Extension	3.00±1.00	3.67±1.53	5	66.67/36.32	0.074/0.270
Supination	78.33±4.16	79.00±6.24	85	8.51/7.59	0.109/0.238
Pronation	83.33±3.51	84.00±5.29	90	8.00/7.14	0.081/0.188

Interpretation: Elbow joint demonstrated relatively preserved flexibility with non-significant deficits across all parameters. The 6-8% supination/pronation deficits suggest mild biceps brachii and pronator muscle tightness.

3.3 Wrist joint assessment

Table 3. Wrist joint flexibility measurements

Movement	Left (°)	Right (°)	Reference (°)	Deficit (%)	p-value
Flexion	75.33±6.11	75.67±3.06	90	19.47/18.94	0.053/0.015*
Extension	80.00±5.20	79.00±4.58	85	6.25/7.59	0.238/0.151
Radial Deviation	49.33±1.53	50.00±4.00	55	14.49/10.00	0.023*/0.185
Ulnar Deviation	71.33±2.52	70.33±5.51	75	5.14/6.64	0.128/0.291

*Significant at p<0.05

Significant Findings: Right wrist flexion (p=0.015) and left radial deviation (p=0.023) demonstrated statistically significant deficits, indicating wrist flexor tightness and occupational use patterns.

4. DISCUSSION

4.1 Scapulohumeral joint patterns

The shoulder joint demonstrated the most substantial flexibility limitations. Statistically significant deficits in left shoulder extension (36.36%, p=0.043), external rotation (12.5%, p=0.038), internal rotation (15.85%, p=0.025), and frontal abduction (19.47%, p=0.037) suggest rotator cuff and scapular stabilizer inflexibility consistent with modern postural dysfunction syndromes (Kebaetse et al., 1999; Straker et al., 2018).

Rotational Deficits: The 10-15% deficits in shoulder rotation carry particular clinical significance, directly associated with shoulder impingement syndrome, glenohumeral instability, and throwing athlete pathology (Ludewig & Reynolds, 2009; Wilk et al., 2011; Kibler & Sciascia, 2016). Reduced external rotation decreases subacromial space, increasing rotator cuff tendon compression risk.

Frontal Plane Limitations: The dramatic 19.47% abduction deficit ($p=0.037$) represents the most substantial restriction, implicating scapulothoracic dyskinesis and inferior capsule restriction (Kibler et al., 2013; Neviaser & Hannafin, 2010). This finding correlates with increased rotator cuff tendinopathy incidence through altered glenohumeral mechanics.

4.2 Elbow, forearm, and wrist mobility

The elbow exhibited preserved flexibility (2-3% flexion deficit, non-significant), indicating the hinge joint's structural simplicity maintains functional range effectively. However, the 6-8% supination/pronation deficits suggest biceps brachii and pronator muscle tightness related to occupational positioning (Sommerich et al., 2001).

Wrist joint variability, with significant right flexion (18.94%, $p=0.015$) and left radial deviation (14.49%, $p=0.023$) deficits, reveals directional asymmetry consistent with computer use ergonomics. Keyboard positioning promotes wrist extension, paradoxically shortening extensors while lengthening flexors (Cook et al., 2014). The significant radial deviation deficit may represent early median nerve tension signs (Buschbacher, 1999; Rempel et al., 1998).

4.3 Bilateral asymmetry and clinical implications

Left-side predominance of flexibility restrictions (shoulder rotations, abduction, wrist radial deviation) suggests handedness effects and unilateral use patterns creating functional imbalances. Bilateral asymmetries >10% associate with increased musculoskeletal injury risk (Knapik et al., 1991; Croisier et al., 2008).

These subclinical deficits represent modifiable risk factors for: shoulder impingement syndrome, adhesive capsulitis, rotator cuff pathology, carpal tunnel syndrome, and occupational overuse injuries. Early identification through objective digital assessment enables preventive interventions before symptom manifestation.

4.4 Mobee Med technology advantages

This investigation validates several theoretical advantages of digital goniometry:

Precision: ±0.5° accuracy eliminates the 5-10° error margins of manual goniometry (Rothstein et al., 1983; Norkin & White, 2016).

Standardization: Neutral-zero method with real-time feedback ensures consistent positioning, eliminating inter-rater reliability problems (Bovens et al., 1990).

Multi-planar Assessment: Three-axis gyroscope captures complex movements (horizontal shoulder movements, forearm pronosupination, ankle eversion/inversion) impossible with traditional goniometers.

Comprehensive Documentation: Pain recording, bilateral comparison, and serial assessment functions facilitate clinical decision-making and treatment monitoring.

4.5 Clinical recommendations

Shoulder Complex:

- Posterior capsule stretching (cross-body adduction, sleeper stretches)
- Rotator cuff strengthening with external rotator emphasis
- Scapular mobilization targeting levator scapulae/upper trapezius
- Postural correction and ergonomic modifications

Elbow/Forearm:

- Biceps stretching (extended elbow with supinated forearm)
- Eccentric loading exercises for sarcomere adaptation
- Pronator/supinator balance through full ROM resistance training

Wrist/Hand:

- Wrist flexor stretching with neural mobilization

- Carpal joint mobilization techniques
- Ergonomic keyboard positioning
- Median/ulnar nerve gliding exercises

General Principles: Daily stretching (30-60 second holds, 3-5 repetitions), gradual intensity progression, functional movement integration (Freitas et al., 2018; Page, 2012; Behm & Chaouachi, 2011).

4.6 Study limitations

Sample size (n=3) provides insufficient power for definitive conclusions; larger studies (n≥30) are needed. Population characteristics (young, healthy adults) limit generalizability to pediatric, elderly, or clinical populations. Cross-sectional design precludes test-retest reliability assessment and longitudinal tracking. Measurement considerations: active-only assessment, no warm-up protocol, time-of-day effects not controlled. Contextual factors: occupational history, training background, genetic joint laxity, anthropometric influences not systematically documented.

4.7 Future research directions

Large-scale normative database development (n>1000) with age/sex/occupation stratification

Clinical validation studies comparing Mobee Med with radiographic ROM assessment

Randomized controlled trials evaluating stretching protocols with objective outcomes

Prospective cohort studies linking baseline flexibility to injury incidence

Special population applications (geriatric, pediatric, post-surgical, occupational screening)

Technology integration (smartphone applications, telehealth, wearable sensors, AI pattern recognition).

5. CONCLUSIONS

This preliminary investigation reveals significant upper extremity flexibility deficits in healthy young adults despite the absence of clinical symptoms. Key findings include:

Scapulohumeral joint: most substantial limitations with statistically significant deficits in left extension (p=0.043), external rotation (p=0.038), internal rotation (p=0.025), and frontal abduction (p=0.037), indicating rotator cuff and scapular stabilizer inflexibility;

Elbow/forearm: relatively preserved flexibility with non-significant deficits, reflecting hinge joint simplicity and consistent daily use;

Wrist/hand: variable findings with significant right flexion (p=0.015) and left radial deviation (p=0.023) restrictions, suggesting occupational and handedness-related patterns;

Bilateral asymmetries: left-side predominance indicating handedness effects and unilateral use patterns requiring clinical attention;

Technological validation: Mobee Med demonstrated superior capabilities versus traditional methods: ±0.5° precision (eliminating 5-10° goniometer errors), automated measurement (removing observer bias), neutral-zero standardization (ensuring consistent positioning), three-axis capture (measuring complex multi-planar movements), and integrated documentation (pain recording, bilateral comparison, longitudinal tracking);

Clinical significance: identified subclinical deficits represent modifiable risk factors for shoulder impingement, adhesive capsulitis, rotator cuff pathology, carpal tunnel syndrome, and occupational injuries. Early detection enables preventive interventions before symptom manifestation, potentially reducing healthcare costs and improving long-term outcomes;

Practical impact: integration of digital goniometry into routine screening protocols, baseline flexibility establishment for high-risk occupations, preventive stretching program implementation, objective progress monitoring at 4-6 week intervals, and bilateral asymmetry >10% consideration as injury risk indicators;

Final statement: digital goniometry using Mobee Med provides precise, objective, comprehensive upper extremity flexibility assessment superior to traditional methods. Even healthy young adults demonstrate significant subclinical ROM deficits warranting preventive intervention. Integration of emerging technologies into routine clinical practice represents an essential advancement for evidence-based musculoskeletal healthcare.

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7. CONFLICTS OF INTEREST

The authors declare no conflicts of interest. Mobee Med equipment was provided institutionally without commercial relationship or financial arrangement with the manufacturer.

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