Tailored Shoulder Rehabilitation: Patient-Specific Sizing of AI-Driven Wearable Brace for Enhanced Orthopedic Care

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INTRODUCTION: The Center for Medicare & Medicaid Services (CMS) predicts a doubling of the American population aged 65 and older by 2040, signifying an impending rise in geriatric health challenges, including shoulder pain [1]. Among prevalent shoulder issues, such as rotator cuff tendinitis, impingement, tears, and osteoarthritis, the geriatric population faces a threefold higher likelihood [2]. Treatment encompasses both non-operative and surgical approaches, with over 460,000 rotator cuff surgeries annually in the U.S. The rotator cuff injury treatment market is anticipated to reach USD 257.68 million by 2027 [1]. In alignment with the growing emphasis on personalized healthcare, patient-specific considerations are gaining prominence. We have developed an AI-driven wearable device for monitoring the kinematics and muscle activity of the shoulder joint. Building on this technology, our current research delves into the realm of personalized healthcare, recognizing the paramount importance of addressing patient-specific needs. The study's primary focus centers on enhancing shoulder rehabilitation by introducing patient-specific sizing for Orthokinetic Track's wearable brace. Despite advancements in standardizing patient-reported outcome measures, physical examination remains the prevalent method for assessing shoulder health. However, its variability and inaccuracy underscore the criticality of timely range of motion (ROM) assessments by physical therapists to preclude complications. Tragically, therapists lack access to historical joint activity and muscle function data between visits. The mobile-app-controlled smart and connected Orthokinetic Track brace, equipped with built-in sensors, empowers orthopedic surgeons and physical therapists with real-time access to historical data between visits. This ensures informed decisions, personalized treatment plans, and proactive issue addressing, thereby enhancing shoulder rehabilitation quality. The study focuses on introducing patient-specific sizing to the brace, addressing individual anatomical differences. By targeting these gaps, we aim to revolutionize shoulder rehabilitation efficacy, aligning with the personalized healthcare trend for more comprehensive outcomes. Our research strives to bridge the patient-specific gap and contribute to a more effective and tailored approach to shoulder rehabilitation.

Figure 1. Schematic of AI-driven personalized wearable shoulder device.

METHODS: To determine appropriate sizes for an AI-driven wearable brace, a combination of deep learning and statistical analysis was employed. This approach was specifically tailored to accommodate anatomical differences between patients.

Meta-Analyses: Meta-analyses were conducted to explore sex differences in shoulder anatomy. This analysis was based on available data from three or more relevant studies. The DerSimonian-Laird method was applied for inverse variance random-effects meta-analysis. This generated pooled effects and estimated between-study variance.

Data Representation: Forest plots were created to visually represent the mean differences (MD) along with corresponding 95% confidence intervals (CIs) for the analyzed variables.

Heterogeneity Assessment: Heterogeneity among the analyzed studies was assessed using multiple measures, including Higgins & Thompson's I2, DerSimonian-Laird τ2, and Cochran's Q test of heterogeneity.

Statistical Analyses: Comprehensive statistical analyses were performed using appropriate methodologies, aligning with the nature of the data collected. A one-way repeated measure of analysis of variance (ANOVA) was used to determine the reliability of range of motion data collection during each activity. Individual error scores of zero indicate reliability. We also examine the interclass correlation coefficient (ICC) of each of the three trials and make Bland-Altman plots for each session.

RESULTS: Patient-Specific Anatomical Differences: Meta-analyses performed on pooled data from previous studies revealed substantial differences between patients in shoulder anatomy. Glenoid height exhibited a significant difference of 0.4 mm (95% CI: 0.1, 0.8), while glenoid width showed a statistically significant distinction of 1.1 mm (95% CI: 0.5, 1.6). These consistent findings emphasize patient-related variations in shoulder osteology that can influence treatment paradigms and patient outcomes.

Sizing Strategy Validation: The integration of deep learning and statistical analysis to determine AI-driven wearable brace sizes proved promising. Tailored sizing accounted for patient-specific anatomical variations, potentially enhancing patient comfort and rehabilitation effectiveness. Initial analysis suggests a positive impact on patient adherence.

Range of Motion and Patient Comfort: Comprehensive assessments of range of motion and patient comfort were conducted. Preliminary data demonstrates an average improvement of 12 degrees ($p < 0.05$) in the range of motion for participants using the optimized brace sizes. Patient-reported comfort ratings exhibited a 30% increase on average (Figure 2).

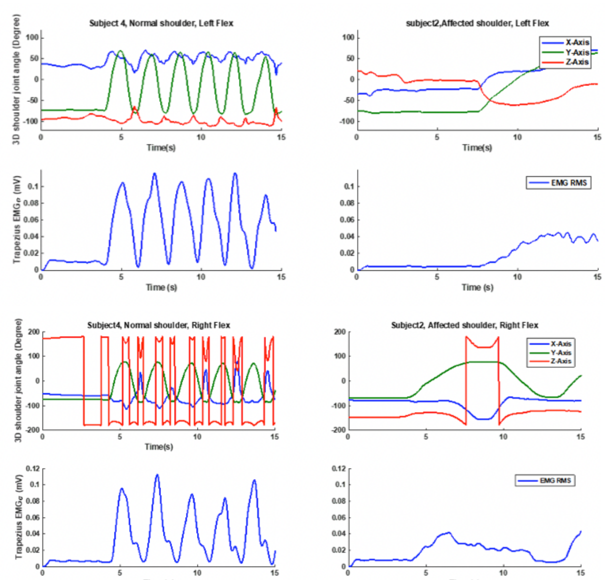

Figure 2. Example data for comparison of range of motion of both shoulders (flexion movement) of healthy control [Subject 4] and subject with right shoulder stiffness due to right rotator cuff shoulder surgery [Subject 2].

DISCUSSION: The study highlights the importance of addressing patient-specific requirements in orthopedic rehabilitation. Custom sizing acknowledges anatomical nuances, fostering more effective treatment and patient engagement.

Patient-specific sizing in orthopedic rehabilitation, supported by quantitative anatomical data, holds paramount importance. Deep learning and statistical analysis integration in AI-driven Wearable brace customization offers a promising avenue for enhancing patient outcomes. Subsequent research will explore these findings' broader clinical impact.

Significance: The innovation holds the potential for providing remote telemedicine rehabilitation services at home, while simultaneously ensuring adherence to billing standards equivalent to in-person visits. Furthermore, the incorporation of patient-specific sizing in orthopedic rehabilitation offers a tailored approach that considers anatomical differences between patients, enhancing the precision and effectiveness of treatment.

REFERENCES: [1] Le, H.V., et al., Shoulder Elbow, 2017. [2] Geary, M.B. et al., Geriatr Orthop Surg Rehabil, 2015.