The Influence of Hand Dominance on Active Range of Motion in Bimanual Tasks: A Motion Analysis Study

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INTRODUCTION: Daily functioning relies on activities of daily living (ADLs), which encompass essential tasks for individuals. Understanding the biomechanics involved in these tasks is crucial, particularly for patients with musculoskeletal or neurological deficiencies. Active range of motion (AROM) provides insights into joint mobility and functional capacity specific to task completion. However, the impact of hand dominance on AROM in bimanual tasks remains unclear. This study used motion analysis techniques to analyze joint motion in toothpaste-toothbrush application and water bottle opening/closing tasks. By comparing dominant and non-dominant hand performance, we aimed to uncover any significant differences. These findings contribute to our understanding of hand dominance and AROM in bimanual tasks, offering potential implications for tailored interventions in patients with musculoskeletal or neurological impairments.

METHODS: A total of 25 healthy subjects performed two ADLs: a toothbrush task and a bottle task. A Vicon Vero motion capture system was employed to capture three-dimensional (3D) movement data. All procedures were approved by the local institutional review board, and informed consent was collected. Twenty-one motion capture markers were placed on the subjects' upper extremities (UE) and torso to track shoulder, elbow, and wrist joint movements. Each participant performed three repetitions of each task. They were asked to perform the task as they would normally, without specification of which hand to use for each part of the task. In the toothbrush task, subjects were instructed to uncap the toothpaste, apply it to a toothbrush held in their hand, and then place both items back on the table. For the bottle task, participants were instructed to remove the screw-on cap of a plastic water bottle, then re-cap the bottle and put it back onto the table.

The recorded data underwent processing to remove noise and artifacts, ensuring the accuracy of the subsequent analysis. AROM was calculated for each trial by subtracting the maximum and minimum joint angles observed during the task. MATLAB software was used for the AROM calculations of each joint. To assess the impact of hand dominance, the mean difference in AROM between the dominant and non-dominant limbs was determined. The dominant limb was identified based on self-reported hand dominance provided by the subjects. A positive mean difference indicated greater AROM in the dominant joint. Statistical analysis was performed using paired t-tests to examine significant differences between the AROM of the dominant and non-dominant limbs for each joint. The significance level was set at $p < 0.05$.

RESULTS SECTION: Table 1 and table 2 show the differences in active range of motion between dominant and non-dominant limb for each joint during the toothbrush and bottle task respectively.

DISCUSSION: The bottle opening task revealed notable disparities in active range of motion (AROM) between the dominant and non-dominant limbs, primarily observed in the wrist and shoulder joints. Notably, while not instructed to do so, all subjects used their dominant hand to unscrew the bottle, and non-dominant hand to hold the bottle. Interestingly, the data suggests that the non-dominant wrist and dominant shoulder exhibited greater AROM during this task. Given the specific demands of opening a bottle, including grip technique, torque generation, and manipulation of the bottle cap, distinct motion patterns and joint requirements between limbs are likely contributing factors. These findings reinforce the inherent asymmetry involved in the task of opening a bottle, as supported by AROM measurements. Additionally, the consistent performance of tasks in a particular manner may contribute to the engrainment of these differences over time.

Conversely, the toothbrush task did not demonstrate significant differences in AROM. Despite each hand fulfilling a distinct role, involving toothbrush holding or toothpaste squeezing, this task may entail similar motion patterns between the limbs.

In summary, the results highlight significant discrepancies in joint motion between the dominant and non-dominant hands during the bottle opening task, while the toothbrush task does not exhibit such variations. These observations underscore the impact of hand dominance, task-specific demands, and motor integration on joint motion during bimanual tasks.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): This study provides normative values for the difference in AROM based on hand dominance for activities of daily living. Understanding the biomechanics provides a reference for evaluation of patients with unilateral trauma or neuromuscular disorders such as cerebral palsy.

IMAGES AND TABLES: Images and tables will appear at the end of the abstract and must be sized to fit within the abstract. Three images and/or tables are allowed per abstract.

Table 2: Bottle task differences in dominant and nondominant AROM

Joint (dimension)	Mean Difference (°)	Confidence Interval (°)	p-value
Wrist (flexion)	-1.86	[-11.22, 7.49]	0.68
Wrist (abduction)	-7.11	[-12.68, -1.53]	0.01
Wrist (internal rotation)	-12.42	[-25.25, 0.42]	0.06
Elbow (flexion)	1.23	[-3.13, 5.59]	0.58
Shoulder (flexion)	4.72	[0.80, 8.64]	0.02
Shoulder (abduction)	10.18	[0.02, 20.34]	0.05
Shoulder (internal rotation)	-0.41	[-3.94, 3.12]	0.79

Table 1: Toothbrush task differences in dominant and nondominant AROM

Joint (dimension)	Mean Difference (°)	Confidence Interval (°)	p-value
Wrist (flexion)	-0.07	[-11.72, 11.57]	0.98
Wrist (abduction)	0.57	[-3.82, 4.96]	0.81
Wrist (internal rotation)	5.84	[-3.73, 15.42]	0.22
Elbow (flexion)	1.64	[-1.17, 4.45]	0.26
Shoulder (flexion)	0.80	[-2.06, 3.65]	0.59
Shoulder (abduction)	1.72	[-4.10, 7.54]	0.56
Shoulder (internal rotation)	1.20	[-1.87, 4.28]	0.45