# Accuracy of Kinect for Measuring Shoulder Joint Angles in Multiple Planes of Motion

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***Abstract*—The present study aimed to test the validity of upper extremity joint angle measurements with the Microsoft Kinect for shoulder rehabilitation. Results indicate that there are large discrepancies in measured shoulder angles from the Kinect compared to the gold standard (magnetic tracker) and the clinical standard (goniometer). Before the Kinect can be used to measure movements for clinical rehabilitation, understanding its limitations in precision and accuracy of measuring specific joint motions is imperative.**

***Keywords—measurement accuracy; validity; Kinect;***

## I. Introduction

Virtual reality-based physical rehabilitation, or virtual rehabilitation, provides several advantages over conventional therapy, including an increased capacity to obtain quantitative measures to track motor performance, deliver real-time performance feedback, and enhance patient motivation. By exploiting the latest commercial game technologies, such as the Nintendo Wii™ [1], the Microsoft Xbox™ [2], and the Sony Playstation 3™ [3,4], virtual rehabilitation systems are being developed at increasingly low costs, making them ideal for administering in-home therapy. These gaming technologies were not developed with intention of clinical use however. Thus, the accuracy of their measurements must be thoroughly evaluated before it can be applied to rehabilitation. As with all new sensing systems, measurement accuracy for the specific measurement of interest should be thoroughly assessed before practical and, even more importantly, clinical purposes.

With the ultimate goal of developing a virtual rehabilitation system for post-operative shoulder therapy, this study aimed to assess the validity of the popular Microsoft Kinect™ for measuring shoulder angles. Previous work of Bonnechère et al. [5] found the skeletal data from the Kinect for Windows SDK to be valid for measuring the range of motion in shoulder abduction. However, this study did not investigate whether Kinect could also measure exact shoulder angles; furthermore, only one plane of shoulder movement was considered. A study by Fernández-Baena et al. [6] also examined accuracy of the Kinect for measuring shoulder range of motion and observed average errors between 8 and 14 degrees in shoulder angle trajectories. Chang et al. [7] similarly observed large errors when tracking the shoulder position with the Kinect. However, no formal analyses of validity were conducted. Moreover, these two studies used the skeletal data from OpenNI (Primesense), which is different from the skeletal data from the Kinect for Windows SDK. Huber et al. [8, 9] compared shoulder angle measurements from the Kinect for Windows SDK (v1.6) with 3D motion capture and goniometer measurement, which yielded alarming results. The discrepancies between the Kinect and the two standard measurements were found to be clinically significant as errors exceeded ±5°. To further assess the Kinect's accuracy for a wider range of shoulder angles, this study expanded the number of examined shoulder configurations and again compared shoulder angle measurements from the Kinect with a 3D motion analysis system (gold standard) and goniometer measures (clinical standard).

## II. Methods

Ten healthy participants (6 females and 4 males; mean age 21.4 ± 3.2 years) were recruited using a sample of convenience from a university-based population. All participants agreed to participate and signed the University's Institutional Review Board approved informed consent.

Each participant held a series of 11 static shoulder poses, each measured twice, but in fully randomized order. Three planes of motion were examined: external rotation in a 90 degree abducted position (0°, 30°, 60°), flexion (30°, 60°, 90°, 120°) and abduction (30°, 60°, 90°, 120°). Half of the participants performed the shoulder motion with the dominant arm and the other half with the non-dominant arm. Measurements for each pose were simultaneously recorded using three modalities: (1) Kinect for Windows camera (skeletal data from the Kinect for Windows SDK v1.6) (2) 3D motion analysis system (Acension Trakstar), and (3) a blinded goniometer. The 95% limits of agreement (LOA) between the Kinect and the two measurement standards, goniometer and 3D motion analysis, were computed for each pose type to determine validity [10]. The 95% LOA were defined as the mean difference ±1.96 standard deviation of the differences, such that 95% of differences lay within these limits. If the 95% LOA were greater than ±5°, then the discrepancies between measurement systems were considered clinically significant.

This work was supported with a Northeastern University Tier 1 Provost Grant and by The Mathworks.

### III. Results

For all 11 poses, the 95% LOA were two to five times greater than ±5°, as summarized in Table 1. This indicated that the discrepancies between measurement systems were clinically significant. Fig. 1 shows that for all poses the mean difference between measurements was non-zero. In addition to this offset there were large variations in measurement differences.

TABLE I. 95% Limits of Agreement

| Pose Type | 95% LOA | |
|---|---|---|
| | ***With Goniometer*** | ***With 3D Motion Analysis*** |
| Flexion | ±11.72° | ±19.04° |
| Abduction | ±11.96° | ±18.46° |
| External Rotation at 90° Abduction | ±25.32° | ±21.71° |

### IV. Conclusions

While the skeletal data of Kinect for Windows SDK may be sufficiently accurate for commercial gaming purposes, this study revealed a significant concern for using these data in clinical applications where precise angle measurements are required. The large discrepancies in shoulder angle measurements should not be taken lightly as accurate shoulder angle measurements are required for most musculoskeletal and neurological rehabilitation protocols [4,6,7]. Before the Kinect can be used to measure movements in virtual rehabilitation, it is imperative to understand its limitations in precision and accuracy for measuring specific joint motions.

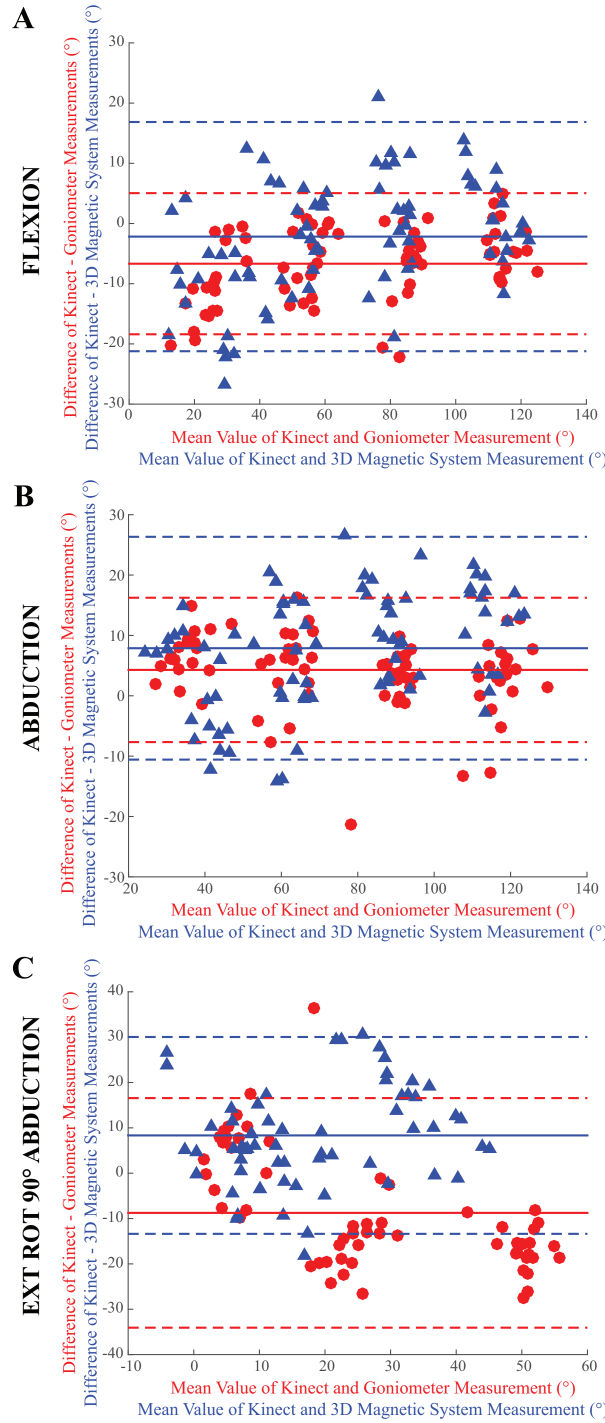


Fig. 1. Bland-Altman plots for each pose type: (A) flexion, (B) abduction, and (C) external rotation at 90° abduction. Results indicate the difference in shouler angle between the Kinect and goniometer (red circles) and the Kinect and the 3D magnetic tracking system (blue triangles). The solid lines represent the mean difference between the Kinect and goniometer (red) and the Kinect and 3D magnetic tracking system (blue). The dashed lines represent the mean difference ± 95%.

### References


[1] J. E. Deutsch *et al.*, "Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy," *Phys. Ther.*, vol. 88, no. 10, pp. 1196–207, Oct. 2008.

[2] K. Morrow *et al.*, "Low-cost virtual rehabilitation of the hand for patients post-stroke," in *Virtual Rehabilitation, 2006 International Workshop on*, 2006, pp. 6–10.

[3] M. Huber *et al.*, "Feasibility of modified remotely monitored in-home gaming technology for improving hand function in adolescents with cerebral palsy," *IEEE Trans. Inf. Technol. Biomed.*, vol. 14, no. 2, pp. 526–34, Mar. 2010.

[4] M. R. Golomb *et al.*, "In-home virtual reality videogame telerehabilitation in adolescents with hemiplegic cerebral palsy," *Arch. Phys. Med. Rehabil.*, vol. 91, 2010.

[5] B. Bonnechère *et al.*, "Validity and reliability of the Kinect within functional assessment activities: comparison with standard stereophotogrammetry," *Gait Posture*, vol. 39, no. 1, pp. 593–8, Jan. 2014.

[6] A. Fernandez-Baena, A. Susin, and X. Lligadas, "Biomechanical validation of ppper-body and lower-body joint movements of Kinect motion capture data for rehabilitation treatments," in *2012 Fourth Int. Conf. Intell. Netw. Collab. Syst.*, Sep. 2012, pp. 656–661.

[7] C. Y. Chang *et al.*, "Towards pervasive physical rehabilitation using Microsoft Kinect," in *International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, 2012, pp. 159–162.

[8] M. E. Huber *et al.*, "Validity and reliability of Kinect for measuring shoulder joint angles," in *Northeast Bioengineering Conference (NEBEC), 2014 40th Annual*, Apr. 2014, pp.1-2.

[9] M. E. Huber *et al.*, "Validity and reliability of Kinect skeleton for measuring shoulder joint angles", *Physiotherapy*, 2015.

[10] J. Martin Bland and D. Altman, "Statistical methods for assessing agreement between two methods of clinical measurement," *Lancet*, vol. 327, no. 8476, pp. 307–310, Feb. 1