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Camera-tracking gaming control device for evaluation of active wrist flexion and extension

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ABSTRACT

Study Design: Cross sectional.
Introduction: Measuring wrist range of motion (ROM) is an essential procedure in hand therapy clinics.
Purpose of the Study: To test the reliability and validity of a dynamic ROM assessment, the Camera Wrist Tracker (CWT).
Methods: Wrist flexion and extension ROM of 15 patients with distal radius fractures and 15 matched controls were assessed with the CWT and with a universal goniometer.
Results: One-way model intraclass correlation coefficient analysis indicated high test-retest reliability for extension (ICC = 0.92) and moderate reliability for flexion (ICC = 0.49). Standard error for extension was 2.45° and for flexion was 4.07°. Repeated-measures analysis revealed a significant main effect for group; ROM was greater in the control group ($F[1, 28] = 47.35$; $P < .001$). The concurrent validity of the CWT was partially supported.
Conclusion: The results indicate that the CWT may provide highly reliable scores for dynamic wrist extension ROM, and moderately reliable scores for flexion, in people recovering from a distal radius fracture.
Level of Evidence: N/A.

Introduction

Complications after distal radius fractures are common and involve the skin, tendons, nerves, fascia, blood vessels, and bones. About a year after injury, 20% of clients will still be symptomatic, with 10% having a significant functional limitation.[1,2] Clinicians assess wrist and hand function to identify impairment, activity limitation, and participation restriction, to monitor the effectiveness of treatment, and to evaluate permanent disability to help determine financial compensation and or the need for vocational retraining.[3-7]

Measuring wrist range of motion (ROM) of the injured wrist is considered to be an essential procedure within hand therapy clinics. The goniometer is the conventional evaluation tool used to measure active and passive ROM of the injured wrist and is commonly used by hand therapists and researchers (eg, Clarkson[8]) for measuring ROM. Provided that standard guidelines are followed, goniometric measures of ROM are valid and reliable.[8-14] However, measurement with a goniometer is performed under conditions that entail static, nonfunctional movements, and thus, it is less likely to depict complex dynamic movement of the wrist during the performance of daily tasks.

Over the years, alternate methods have been proposed to add information available from the goniometer for the measurement of wrist ROM. These include electrogoniometers,[13] glove-based devices,[6] exoskeleton-type apparatus,[15] and wearable sensors.[16] Many

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of these methods overcome the limitation of static ROM measures but have other drawbacks including encumbrance and difficulty in aligning the sensor to the joint axis[16,17] which impede the natural performance of an activity. An alternate class of instruments is marker-based camera tracking,[18-20] which does not encumber the client's limb and is usually more accurate in identifying axes of rotation.[21] However, these systems tend to be expensive and require customized equipment and expertise which are not readily available. They have been applied primarily in the assessment and treatment of hand function resulting from neurologic impairments.[21,22]

These technologies have not been used extensively for clients who have dysfunction as a result of fractures, arthritis, or surgery. Nica[23,24] reported the use of the Pablo Virtual Reality tool for evaluation of hand dysfunction of 54 patients after hand surgery for various traumatic injuries. Virtual Reality enables an accurate assessment during an activity where examinee attention in not focused on the movement itself but rather on completion the task, as he or she would do in real life.[25,26]

A simple, camera-tracking gaming system was developed by Yeh et al.[27] It is an optical tracking device that uses low-cost, dual webcams to track the motion of 2 light-emitting diodes (LEDs) providing 6° of freedom with a sampling rate of 60 Hz. This device enables interaction within a virtual gaming environment. An initial study of the optical tracking device compared its utility relative to Ascension's Flock of Birds 6° of freedom magnetic tracking system.[27] Both the optical and magnetic tracking devices scored highly in user perception questionnaires and the optical tracker performed as well as a magnetic tracking system for game tasks. The developers selected an airplane task as an intuitive target tracking game that could provide feedback to the user and be readily adjusted to change the speed and location of target stimuli and thus the ROM required to perform the task. A similar task has been used by previous researchers to examine ankle dorsiflexion or plantarflexion and inversion or eversion.[28]

The potential of this device as a dynamic assessment tool as well as a lack of studies that examined the use of low-cost, camera-tracking gaming systems for orthopedic hand injuries led to the aim of the present study to investigate the usability of the Camera Wrist Tracker (CWT), an adapted version of Yeh et al's[27] optical tracking device, as a dynamic (ie, measurement during movement), clinical measurement tool of active ROM (AROM) for wrist flexion and extension. Specifically, the objectives of this study were to examine (1) test-retest reliability of AROM measurements as determined by the CWT; (2) the construct validity of the CWT by comparing the results of people with wrist fractures to those of a noninjured control group; and (3) the concurrent validity of the CWT by comparing active flexion and extension of the wrist as measured by the CWT to these joint rotations as measured with a goniometer.

We hypothesized that there will be high test-retest reliability of AROM measurements with the CWT. In addition, AROM measurements of patients with distal radius fractures will be significantly lower than AROM measurements of the control participants. Finally, we hypothesized that significant correlations (known group validity) will be found between wrist AROM as measured by the CWT and by a universal full-circle goniometer, as well as acceptable agreement between the 2 measurements.

Methods

Participants

The patient group included 15 adult participants with distal radius fractures who were referred to occupational therapy specialists in hand rehabilitation. Participants were included in the study if they had the ability to grip the device (ie, participants who could grip the CWT handle without considerable effort), could pronate their affected arm at least 85°, and had at least 15° AROM of wrist flexion and extension. They were excluded if they had cognitive impairment as indicated in their medical records, comorbidity such as complex regional pain syndrome or other confounding pathologies (eg, diabetes). The control group included 15 healthy participants who were matched to the patient group for age, gender, hand dominance, and profession.

Instruments

CWT

As described previously, the original optical tracking device was developed by Yeh et al.[27] The device (Fig. 1) was adapted by an occupational therapist and mechanical engineer to improve the hand grip and to comply with ergonomic guidelines. Participants were seated according to ergonomic guidelines with feet flat on the floor, the hips, and lower back supported against the chair backrest, the knees flexed at approximately 90° and the elbows are slightly flexed with forearms resting comfortably on the device.[29,30]

In the present study, a single web camera was positioned to capture the sagittal plane motion (wrist flexion and extension; Figs. 2A and 2B). The participants sat with their forearm supported, to isolate wrist movement from more proximal joint movements, and grasped the hand-held LED unit (Fig. 3) while viewing a monitor placed in front of them. The game task was to steer a virtual airplane through rectangular frames of varying heights visually displayed in a virtual environment; ambient sounds of the airplane motor were heard during the game. To perform this task, the participants flexed and extended their wrists to move the LED unit thereby navigating the airplane through 15 successively displayed target rectangles. The position of successive rectangles was increased to elicit greater ROM as the trial continued. For wrist extension, the height of the rectangles increased and for wrist flexion, it decreased. Movement of the CWT was translated by a software algorithm into angles of movements. For each rectangle, we obtained about 70 data points during AROM from which were computed the minimum range, maximum range, mean range, and standard deviation (SD). The AROM for wrist flexion is indicated by a minus sign ("−") to differentiate from the AROM for wrist extension which is indicated by a plus sign ("+").

The system thus provided dynamic information regarding active flexion and extension of the wrist in degrees for the whole path. The AROM was measured throughout the dynamic activity until the participants reached the final rectangle and remained there without further movement. This is the maximum AROM achieved

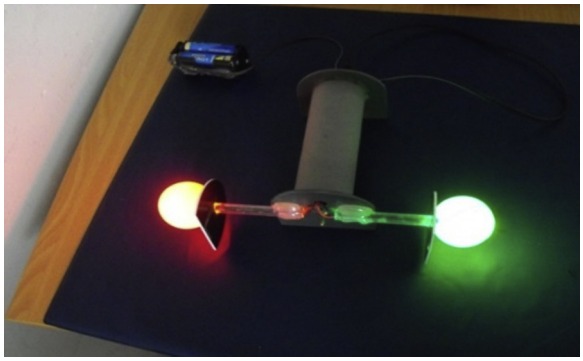

Fig. 1. Hand-held dual LED unit with adapted hand grip. LED = light-emitting diode.