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What is This?
ADAPTING THE FASTRAK® SYSTEM FOR THREE-DIMENSIONAL MEASUREMENT OF THE MOTION OF THE WRIST

C. A. WIGDEROWITZ, I. SCOTT, A. JARIWALA, G. P. ARNOLD and R. J. ABBOUD

From the Department of Orthopaedics and Trauma Surgery, TORT Centre, Ninewells Hospital, Dundee, Scotland and the Institute of Motion Analysis and Research (IMAR), TORT Centre, Ninewells Hospital, Dundee, Scotland

The Polhemus Fastrak® short-range miniature transmitter and mini-receivers allow wrist motion to be measured continually in three dimensions, registering patterns of motion, which until now were difficult to quantify. The current study aimed to determine the applicability and repeatability of the Fastrak® system when assessing wrist movements during a set protocol of activities. The device was found to be easy to use and repeatable; the Fastrak® system showed a mean error of up to 3° in all movements tested. Its assessment of range of motion correlated with the results in the literature. The Fastrak® system was suitable for continuous registration of movements during the performance of set tasks in either of the wrists. It has the potential to be used for documentation of wrist motion in clinics for various pathologies and for assessing outcomes in wrist surgeries. Journal of Hand Surgery (European Volume, 2007) 32E: 6: 700–704

Keywords: the Fastrak® system, continuous wrist motion, three-dimensional assessment, electromagnetic goniometer, normal wrist motion, functional tasks

Dynamic studies of wrist motion and accurate assessment of specific wrist angles during various movements are difficult using simple goniometers, which are limited to measurements in a single plane with poor inter-observer reproducibility. Biaxial goniometers have the added problems of inherent cross-talk and zero-drift errors as a result of forearm rotations (Buchholz and Wellman, 1997). Studies with computed tomography and magnetic resonance are fraught with problems of resource management. Objective scoring systems require validation and are prone to inconsistencies (Bradway et al., 1989).

The Polhemus electromagnetic systems (Isotrak® and Fastrak®) have both been used to measure the spatial positioning and three-dimensional movements of the ankle and the subtalar joints continuously, with low variability and with an error of up to 1° (Rendall and Abboud, 1999). The continuous registration of three-dimensional data enables the registration and analysis of patterns of movements, thus expanding our understanding of joint functions, both in normal subjects and in specific pathologies. A recent development of this system has allowed further miniaturisation of the transmitter and sensors, enabling its use on small joints such as those of the wrist and hand (Leonard et al., 2005).

Before adopting the Fastrak® system for any particular clinical use, it is necessary to assess its suitability. The current study examines the application of the Fastrak® system in the measurement of wrist function. Initially, a device was developed to adjust the Fastrak® system to the wrist and the hand consistently. A protocol of activities was then used to standardise a number of movements performed in activities of daily living. Finally, the Fastrak® system was attached to both wrists sequentially to assess the suitability and repeatability of the system.

MATERIAL AND METHODS

A group of 27 young healthy volunteers was recruited. The subjects were excluded if they had any history of previous wrist trauma, joint disease or suffered from any other condition affecting movement of the upper limbs. Ethical approval was granted for the study by the local research ethics committee.

The Fastrak® system consists of one transmitter and up to four sensors. The transmitter produces an electromagnetic field and determines the three-dimensional position and orientation of the sensors when they are moved within that field. The electromagnetic field range of the miniaturised system is approximately 30 cm³; making it ideal for use on the wrist. We used one sensor for measuring wrist motion for optimum frequency recording (120 Hz). However, up to four sensors can be studied simultaneously by the transmitter at lower frequencies (Polhemus, 2000).

The transmitter was mounted on the dorsum of the forearm, 3 cm proximal to Listers’ tubercle, and held in place with an elastic strap. This location was chosen as it is not affected by movement of the skin folds at the wrist during extension and also has limited soft tissue bulk, thereby minimising motion artefact. The sensor was attached to the dorsum of the hand, superficial to the head of the third metacarpal, so providing adequate distance from the transmitter and, thereby, amplifying small variations in movements. In addition, this position...
is easy to locate and standardise. Finally, as there is very little or no movement in the carpometacarpal joints, the movements at the head of third metacarpal reflect the movements of the wrist. The sensor was attached to the hand with double-sided adhesive tape. The subject’s forearm rested in a custom-built wooden rig, which provided support without restricting the wrist movements. We selected wood as the material for the rig as it does not interfere with the electromagnetic field of the transmitter (Fig 1).

The Fastrak® system was then calibrated in the neutral position in the flexion–extension and the radial–ulnar planes. To do this, the hand was placed in the anatomical position with the axis of the hand coinciding with the long axis of the forearm, which was denoted as the neutral position. This became the reference point from which further movements in the wrists were measured.

The protocol developed for our study consisted of three tasks. The first task (Task 1) measured uni-planar movements of the wrist. The subjects were asked to perform full flexion and extension of the wrist (sagittal motion) and full radial and ulnar deviation (coronal motion). Task 2 involved picking up an object and moving it from the radial to the ulnar side across a 5 cm high barrier and placing it on the other side of the barrier and 10 cm away from it (Fig 2). In the third task (Task 3), the subject was asked to make parallel longitudinal pen marks approximately 5 cm in length moving from the radial to the ulnar side across the board on which the hand was resting and drawing a total of three lines. The latter two tasks investigated wrist motion while performing functional tasks which had been used previously in studies of wrist motion and were noted to be easily understood and simple to perform (Smeulders et al., 2001).

The sequences of tasks were explained and demonstrated to the subjects who were then allowed a short period of training before data collection. Once the task had been learnt, it was performed sequentially with the right and the left hands. After erasing all the marks, the transmitter was remounted on the right wrist and the same task was performed again in what was referred to as ‘Run 2’. This was done to study repeatability.

The comparison between the left and the right wrists was used to investigate the suitability of the system for measurement of movements in either of the two wrists. The range of motion in the relevant planes was extracted from the raw data for analysis.

Statistical analyses using general linear models and paired t-tests were performed on the data.

RESULTS

The Fastrak® system was found to be easily adaptable to the wrist with no substantial discomfort being reported by any of the subjects. No side effects or injuries were noted following its repeated use.

Twenty-seven healthy young volunteers underwent the described measurements. The mean age of this group was 23 (range 18–30) years. There were 15 women and 12 men. Nine were left-handed and 18 were right-handed.

The Fastrak® system acquired the three-dimensional data continuously during performance of the various movement tasks carried out. Fig. 3 illustrates a typical pattern of motion recorded at the wrist during the performance of Task 1 and shows the interlinking of various uni-planar movements of wrist, viz extension, flexion, radial and ulnar deviation. As expected, the maximum movement was noted in the flexion–extension plane. Radial deviation occurred with maximum extension while ulnar deviation occurred with maximal
flexion. The description of movements is limited to those in the flexion–extension plane and in radial–ulnar deviation. The movements in the axial plane were not considered, as they were of very small magnitude with these set tasks and pronation–supination movements occur primarily at the proximal and distal radioulnar joints, which were not studied.

Studying the total arc in the flexion–extension plane, there is little difference between the right and the left wrists (Table 1). It was noted that there was greater flexion of the left wrists as compared to the right wrists. This difference was also identified in the lift and move task (Task 2).

The results of movements in the radial–ulnar deviation are demonstrated in Table 1. There was no statistically significant difference between the movements occurring in the right and left wrists in radial–ulnar deviation. Also, no significant differences were found when the effect of dominance was taken into account.

Table 1—Comparing the left and the right wrists during Task 1

<table>
<thead>
<tr>
<th>Movement</th>
<th>Left wrist (deg) (range)</th>
<th>Right wrist (deg) (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum extension</td>
<td>62 (74–48)</td>
<td>66 (77–57)</td>
</tr>
<tr>
<td>Maximum flexion</td>
<td>65 (82–40)</td>
<td>58 (72–36)</td>
</tr>
<tr>
<td>Total sagittal arc</td>
<td>127 (147–102)</td>
<td>125 (141–94)</td>
</tr>
<tr>
<td>Maximum ulnar deviation</td>
<td>39 (51–29)</td>
<td>40 (54–24)</td>
</tr>
<tr>
<td>Maximum radial deviation</td>
<td>30 (39–14)</td>
<td>30 (44–9)</td>
</tr>
<tr>
<td>Total coronal arc</td>
<td>68 (82–54)</td>
<td>70 (89–40)</td>
</tr>
</tbody>
</table>

Table 2—Demonstrating the ranges of motion for the lift and move task (Task 2)

<table>
<thead>
<tr>
<th>Movement</th>
<th>Mean (deg)</th>
<th>Maximum (deg)</th>
<th>Minimum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R extension direction</td>
<td>21</td>
<td>38</td>
<td>1</td>
</tr>
<tr>
<td>L extension direction</td>
<td>18</td>
<td>51</td>
<td>−7</td>
</tr>
<tr>
<td>R flexion direction</td>
<td>−24</td>
<td>−36</td>
<td>−14</td>
</tr>
<tr>
<td>L flexion direction</td>
<td>−30</td>
<td>−57</td>
<td>−16</td>
</tr>
<tr>
<td>R radial direction</td>
<td>11</td>
<td>33</td>
<td>−9</td>
</tr>
<tr>
<td>L radial direction</td>
<td>13</td>
<td>24</td>
<td>−1</td>
</tr>
<tr>
<td>R ulnar direction</td>
<td>−41</td>
<td>−52</td>
<td>−25</td>
</tr>
<tr>
<td>L ulnar direction</td>
<td>−39</td>
<td>−54</td>
<td>−18</td>
</tr>
</tbody>
</table>

Table 3—Demonstrating the ranges of motion for the writing task (Task 3)

<table>
<thead>
<tr>
<th>Movement</th>
<th>Mean (deg)</th>
<th>Maximum (deg)</th>
<th>Minimum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R extension direction</td>
<td>30</td>
<td>45</td>
<td>8</td>
</tr>
<tr>
<td>L extension direction</td>
<td>28</td>
<td>50</td>
<td>4</td>
</tr>
<tr>
<td>R flexion direction</td>
<td>18</td>
<td>−7</td>
<td>31</td>
</tr>
<tr>
<td>L flexion direction</td>
<td>17</td>
<td>−4</td>
<td>40</td>
</tr>
<tr>
<td>R radial direction</td>
<td>−2</td>
<td>18</td>
<td>−25</td>
</tr>
<tr>
<td>L radial direction</td>
<td>−5</td>
<td>26</td>
<td>−32</td>
</tr>
<tr>
<td>R ulnar direction</td>
<td>−20</td>
<td>−34</td>
<td>−3</td>
</tr>
<tr>
<td>L ulnar direction</td>
<td>−20</td>
<td>−42</td>
<td>14</td>
</tr>
</tbody>
</table>

The results for the writing simulation task (Task 3) showed considerable variability between subjects and between the two wrists of the same individual (Table 3). The total range of movement required to perform this task was relatively small when compared to the total movement possible at the wrist. Again, as above, negative figures indicate flexion and ulnar deviation. There was no statistically significant difference in the mean values of either Task 2 or 3 between the left and the right wrists.
The standard deviation for the movements for all the patients, including ‘Run 2’ was calculated. The standard error of the series of movements in Task 1 is depicted in Table 4. The Fastrak® system revealed a mean variation of up to 3° while comparing the measurements in Task 1 on the right wrist and in ‘Run 2’ (Table 5).

**DISCUSSION**

The Fastrak® system successfully registered the continuous three-dimensional movements of the wrist throughout a wide range of wrist motion. It allowed these measurements to be taken while the subject performed various simple tasks that were devised to mimic common everyday activities. Intraobserver measurements were found to be repeatable, with low error value compared to that reported in the literature for comparable methods (Jonsson and Johnson, 2001; Small et al., 1996; Urban et al., 2002). These findings correlate comparable methods (Jonsson and Johnson, 2001; Small et al., 1996; Urban et al., 2002). These discrepancies may simply reflect variability in the normal population. Our volunteers belonged to a specific group with a small age range, which was different from the other study samples quoted above.

The Fastrak® system demonstrated that most subjects used extension of the wrist while varying from radial to ulnar deviation during the writing-simulating test. It suggests that limitation of these positions may seriously impair ability to write, whilst limitation of flexion and radial deviation are less likely to be relevant. This agrees with previous work on normal wrist movement and function (Brumfield and Champoux, 1984).

Substantial developments in equipment and protocols are still necessary. The concept of dynamic three-dimensional measurements in the wrist is a considerable advance relative to our current static range of movement measurements. The current work largely confirms what is already well-established knowledge regarding patterns of wrist motion. However, additional groups of patients and volunteers with a variety of pathologies and following specific surgical interventions may be studied in the future while performing specific and relevant tasks. Such studies may lead to better understanding of the biomechanics of the hand during different tasks and activities and how it is altered by specific pathological conditions.

**References**


