Functional capacity evaluation
Soer, Remko

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Chapter 4

Test – retest reliability of a WRULD Functional Capacity Evaluation in Healthy Subjects

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Abstract

The aim of this study was to determine test-retest reliability of a Functional Capacity Evaluation for patients with non-specific Work Related Upper Limb Disorders (WRULD FCE). The study sample included 33 healthy adults, consisting of 14 males and 19 females with a mean age of 29.2 years. The WRULD FCE consisted of 8 different tests including 26 items measuring repetitive movements, duration, working in awkward positions, forceful movements and static postures. Two FCE sessions were held with a 10-day interval. Means, 95% confidence intervals, one-way random Intraclass Correlation Coefficients (ICCs), 95% limits of agreement and repeated measures were calculated. An ICC between 0.75 and 0.90 was considered as good and an ICC above 0.90 was considered as an excellent reliability. The results showed that 14 of 26 items (54%) had excellent reliability, 9 of 26 items (35%) had good reliability and 3 of 26 items (11%) had moderate reliability based on ICC values. Significant learning effects were present in the Purdue Pegboard Task and in the Complete Minnesota Dexterity Test. It is concluded that the WRULD FCE is reliable in healthy adults.
Introduction

Work disability in patients with Work Related Upper Limb Disorders (WRULD) due to Visual Display Unit (VDU) work is a major problem in the industrialized world. The existence of physical risk factors for WRULD due to VDU work has been reviewed in different studies [11,12,17]. General outcomes were risk factors related to repetition, duration, working in awkward positions, forceful movements and static muscle contractions. WRULD can lead to pain, numbness, stiffness, loss of strength, coordination and position tolerance of the upper extremity [4]. A reduced physical capacity is assumed. However the assumption of a reduced physical capacity is commonly based on questionnaires. To measure physical capacity, reliable and validated tests are crucial. Therefore a Functional Capacity Evaluation (WRULD FCE) was designed to determine functional capacity of WRULD patients [12]. Content validity of the WRULD FCE was based on a literature search to the relationship of physical risk factors and the development of WRULD due to VDU work [12]. The next step in test development concerns reliability of the WRULD FCE. The aim of this study was to test the WRULD FCE on test-retest reliability in healthy adults.

Methods

Participants
A convenience sample of 33 healthy adults voluntarily participated in this study. Participants were included after providing informed consent and stating that they were healthy. The study sample consisted of 14 men and 19 women. Descriptives of participants are presented in Table 1.

Table 1. Characteristics of participants

<table>
<thead>
<tr>
<th>Gender (n, %)</th>
<th>Male (14, 42%)</th>
<th>Female (19, 58%)</th>
<th>Total group (33, 100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years ± Sd)</td>
<td>32.4 ± 11.4</td>
<td>26.9 ± 8.1</td>
<td>29.2 ± 9.9</td>
</tr>
<tr>
<td>Length (cm ± Sd)</td>
<td>184.9 ± 5.2</td>
<td>172.7 ± 7.2</td>
<td>178.1 ± 8.8</td>
</tr>
<tr>
<td>Weight (kg ± Sd)</td>
<td>81.9 ± 9.1</td>
<td>67.3 ± 11.3</td>
<td>73.8 ± 12.6</td>
</tr>
<tr>
<td>Hand dominance (n, right; n, left)</td>
<td>14 R, 0 L</td>
<td>17 R, 2 L</td>
<td>31 R, 2L</td>
</tr>
</tbody>
</table>

Procedures
Two FCE sessions were held with a 10-day interval to be sure that all participants had recovered from the first FCE session. The FCE was performed in three different locations. After an introduction of the FCE procedures, the participants were briefly instructed on how to perform each test. The evaluator first demonstrated each test. Testing could be terminated for three reasons: 1) it was explained that the participants were allowed to stop the test at any point if they wished to do so, for example because of insecurity, pain or achieving maximal capacity; 2) the evaluator terminated testing if it became unsafe; 3) time limit was reached. All tests were evaluated by a physiotherapist. Eight tests were performed,
including 26 items in total. The tests are: the overhead lift test, the overhead worktest, repetitive reaching test, hand grip strength test, finger strength test, wrist extension strength test, the Purdue Pegboard Task (PP) and the Complete Minnesota Dexterity test (CMDT) [12]. In Appendix 1, the materials, the objectives and the procedures of the FCE are described.

Data analyses
All tests were scored on an interval level. The scores were used for further analyses. Descriptives, oneway random Intraclass Correlation Coefficients (ICCs), 95% confidence intervals (95% CI) and 95% limits of agreement were calculated [1]. ICCs are interpreted as follows: ICC ≥ 0.90 is excellent and sufficient for clinical testing; good when ICC is between 0.75 and 0.90 and poor to moderate when ICC ≤ 0.75 [5]. 95% Limits of agreement were calculated as follows: mean difference ± 1.96 × standard deviation of mean difference [2]. Interpretation of the limits of agreement is a clinical, not a statistical decision [1,16]. To get a global impression of the width of the limits of agreement, a ratio between the limits of agreement and the mean score was calculated. ((1.96 × standard deviation of mean difference)/mean session 1 and 2 × 100%). Paired t-tests were calculated to analyse if the results of the first test session differ from results of the second session. Additionally, ICCs were calculated to measure test-retest reliability among men and women and among the youngest 50th percentile and the oldest 50th percentile of the participants separately. Learning effects in the PP and in the CMDT and a possible decline in hand and finger strength within trials were assumed. A repeated measures design was used for these analyses. All analyses were performed in SPSS.

Results
Of the 33 included participants, 2 could not perform the finger strength test and 1 person could not perform the overhead lift. The results of means, standard deviations, 95% confidence intervals, ICCs and limits of agreement are presented in table 2. ICC values ranged from 0.73 to 0.97 for all tests. Reliability coefficients for handgrip strength of the different positions ranged from 0.86 in position 1 to 0.97 in position 3. For finger strength testing, all ICCs show a good reliability (ICCs > 0.75). The key pinch shows excellent reliability. (ICC = 0.91 right and 0.90 left). Of all 26 test items, three ICC-values did not reach the level of 0.75. These are repetitive reaching right, the PP right and the CMDT left. Of the 23 test items that did reach the 0.75 level (88%), 14 of them reached the 0.90 level of excellent reliability (54%). 95% Limits of agreement ranged from ±9% of the mean score for the CMDT right to ±47% of the mean score for the tip pinch right. A paired t-test showed that participants performed significantly (p < 0.05) better on the second session than on the first session on the overhead lift, repetitive reaching right, the PP and the CMDT (Table 2).
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positions 1 to 0.97 in position 3. For finger strength testing, all ICCs show a good coefficients for handgrip strength of the different positions ranged from 0.86 in

deviations, 95% confidence intervals, ICCs and limits of agreement are presented the person could not perform the overhead lift. The results of means, standard

Of the 33 included participants, 2 could not perform the finger strength test and 1

Chapter 4

Results

Data analyses

objectives and the procedures of the FCE are described.

Minnesota Dexterity test (CMDT) [12]. In Appendix 1, the materials, the

worktest, repetitive reaching test, hand grip strength test, finger strength test, wrist

Results

Table 2. Results of means, differences, standard deviations, 95% CI, limits of agreement and ICCs

<table>
<thead>
<tr>
<th>Test item</th>
<th>Mean 1</th>
<th>Sd 1</th>
<th>Mean 2</th>
<th>Sd 2</th>
<th>Mean difference</th>
<th>Sd of mean difference</th>
<th>95% CI of difference</th>
<th>Limits of agreement</th>
<th>Ratio of LoA and mean (%)</th>
<th>ICC</th>
<th>95% CI of ICC</th>
<th>Interpretation of ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead lift</td>
<td>19.7</td>
<td>6.7</td>
<td>20.8</td>
<td>6.4</td>
<td>-1.1**</td>
<td>2.4</td>
<td>-2.0 to -0.2</td>
<td>-5.8 to 3.6</td>
<td>23</td>
<td>0.92</td>
<td>0.84 to 0.96</td>
<td>Excellent</td>
</tr>
<tr>
<td>Overhead worktest</td>
<td>226</td>
<td>95</td>
<td>231</td>
<td>112</td>
<td>-5</td>
<td>47</td>
<td>-22 to 12</td>
<td>-98 to 88</td>
<td>41</td>
<td>0.90</td>
<td>0.80 to 0.95</td>
<td>Excellent</td>
</tr>
<tr>
<td>Repetitive reaching right</td>
<td>68.6</td>
<td>7.7</td>
<td>65.3</td>
<td>7.9</td>
<td>3.2**</td>
<td>4.8</td>
<td>1.5 to 5.0</td>
<td>-6.2 to 12.6</td>
<td>14</td>
<td>0.74</td>
<td>0.53 to 0.86</td>
<td>Moderate</td>
</tr>
<tr>
<td>Repetitive reaching left</td>
<td>65.5</td>
<td>8.4</td>
<td>64.1</td>
<td>7.1</td>
<td>1.4</td>
<td>5.3</td>
<td>-0.5 to 3.2</td>
<td>-9.0 to 11.6</td>
<td>16</td>
<td>0.76</td>
<td>0.58 to 0.88</td>
<td>Good</td>
</tr>
<tr>
<td>Handgrip strength position 1 right</td>
<td>30.5</td>
<td>8.6</td>
<td>31.9</td>
<td>10.5</td>
<td>-1.5</td>
<td>4.9</td>
<td>-3.2 to 0.3</td>
<td>-11.5 to 8.1</td>
<td>31</td>
<td>0.86</td>
<td>0.74 to 0.93</td>
<td>Good</td>
</tr>
<tr>
<td>Handgrip strength position 1 left</td>
<td>29.6</td>
<td>8.8</td>
<td>31.0</td>
<td>9.9</td>
<td>-1.3</td>
<td>4.5</td>
<td>-2.9 to 0.3</td>
<td>-10.1 to 7.5</td>
<td>29</td>
<td>0.88</td>
<td>0.77 to 0.94</td>
<td>Good</td>
</tr>
<tr>
<td>Handgrip strength position 2 right</td>
<td>42.1</td>
<td>12.1</td>
<td>42.5</td>
<td>13.1</td>
<td>-3.4</td>
<td>4.4</td>
<td>-1.9 to 1.2</td>
<td>-12.0 to 5.2</td>
<td>20</td>
<td>0.94</td>
<td>0.88 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 2 left</td>
<td>38.4</td>
<td>11.7</td>
<td>38.7</td>
<td>12.0</td>
<td>-0.3</td>
<td>3.8</td>
<td>-1.6 to 1.0</td>
<td>-7.8 to 7.2</td>
<td>19</td>
<td>0.95</td>
<td>0.90 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 3 right</td>
<td>40.0</td>
<td>11.6</td>
<td>39.1</td>
<td>11.8</td>
<td>-0.1</td>
<td>2.9</td>
<td>-1.1 to 1.0</td>
<td>-5.8 to 5.6</td>
<td>14</td>
<td>0.97</td>
<td>0.94 to 0.99</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 3 left</td>
<td>34.7</td>
<td>10.9</td>
<td>35.2</td>
<td>10.7</td>
<td>-0.6</td>
<td>3.9</td>
<td>-2.0 to 0.8</td>
<td>-8.2 to 7.0</td>
<td>22</td>
<td>0.93</td>
<td>0.87 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 4 right</td>
<td>34.1</td>
<td>10.0</td>
<td>34.8</td>
<td>10.7</td>
<td>-0.7</td>
<td>3.8</td>
<td>-2.0 to 0.7</td>
<td>-8.1 to 6.7</td>
<td>22</td>
<td>0.93</td>
<td>0.87 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 4 left</td>
<td>30.5</td>
<td>9.1</td>
<td>30.3</td>
<td>9.1</td>
<td>0.2</td>
<td>3.9</td>
<td>-1.2 to 1.6</td>
<td>-7.4 to 7.8</td>
<td>25</td>
<td>0.91</td>
<td>0.83 to 0.96</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 5 right</td>
<td>29.0</td>
<td>9.2</td>
<td>30.0</td>
<td>10.6</td>
<td>-1.0</td>
<td>3.1</td>
<td>-2.1 to 0.2</td>
<td>-7.1 to 5.1</td>
<td>21</td>
<td>0.95</td>
<td>0.89 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Handgrip strength position 5 left</td>
<td>25.7</td>
<td>8.4</td>
<td>26.1</td>
<td>9.1</td>
<td>-0.4</td>
<td>3.1</td>
<td>-1.5 to 0.7</td>
<td>-6.5 to 5.7</td>
<td>23</td>
<td>0.93</td>
<td>0.88 to 0.97</td>
<td>Excellent</td>
</tr>
<tr>
<td>Test item</td>
<td>Mean 1</td>
<td>Sd 1</td>
<td>Mean 2</td>
<td>Sd 2</td>
<td>Mean difference</td>
<td>Sd of mean difference</td>
<td>95% CI of difference</td>
<td>Limits of agreement</td>
<td>Ratio of LoA and mean (%)ψ</td>
<td>ICC</td>
<td>95% CI of ICC</td>
<td>Interpretation of ICC</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------</td>
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<td>--------</td>
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<td>----------------</td>
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<td>----------------------</td>
<td>----------------------</td>
<td>--------------------------</td>
<td>-------</td>
<td>---------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Tip pinch strength right1</td>
<td>5.3</td>
<td>1.0</td>
<td>5.4</td>
<td>1.3</td>
<td>-0.2</td>
<td>1.3</td>
<td>-0.5 to 0.1</td>
<td>-2.7 to 2.3</td>
<td>47</td>
<td>0.76</td>
<td>0.57 to 0.88</td>
<td>Good</td>
</tr>
<tr>
<td>Tip pinch strength left1</td>
<td>5.1</td>
<td>1.4</td>
<td>5.0</td>
<td>1.4</td>
<td>-0.1</td>
<td>0.8</td>
<td>-0.2 to 0.4</td>
<td>-1.7 to 1.5</td>
<td>31</td>
<td>0.82</td>
<td>0.67 to 0.91</td>
<td>Good</td>
</tr>
<tr>
<td>Palmar pinch strength right1</td>
<td>7.7</td>
<td>1.8</td>
<td>7.8</td>
<td>1.7</td>
<td>0.0</td>
<td>1.0</td>
<td>-0.4 to 0.4</td>
<td>-2.0 to 2.0</td>
<td>25</td>
<td>0.84</td>
<td>0.70 to 0.92</td>
<td>Good</td>
</tr>
<tr>
<td>Palmar pinch strength left1</td>
<td>7.3</td>
<td>1.7</td>
<td>7.1</td>
<td>1.5</td>
<td>0.2</td>
<td>0.9</td>
<td>-2.0 to 4.4</td>
<td>-1.6 to 2.0</td>
<td>25</td>
<td>0.85</td>
<td>0.71 to 0.92</td>
<td>Good</td>
</tr>
<tr>
<td>Key pinch strength right1</td>
<td>9.0</td>
<td>1.8</td>
<td>9.1</td>
<td>2.1</td>
<td>-0.1</td>
<td>0.8</td>
<td>-0.4 to 0.2</td>
<td>-1.7 to 1.5</td>
<td>17</td>
<td>0.91</td>
<td>0.82 to 0.95</td>
<td>Excellent</td>
</tr>
<tr>
<td>Key pinch strength left1</td>
<td>8.4</td>
<td>1.7</td>
<td>8.4</td>
<td>1.9</td>
<td>-0.1</td>
<td>0.8</td>
<td>-0.4 to 0.2</td>
<td>-1.7 to 1.5</td>
<td>19</td>
<td>0.90</td>
<td>0.81 to 0.95</td>
<td>Excellent</td>
</tr>
<tr>
<td>Wrist extension strength right1</td>
<td>17.1</td>
<td>4.7</td>
<td>17.6</td>
<td>6.1</td>
<td>0.4</td>
<td>2.3</td>
<td>-1.2 to 0.4</td>
<td>-3.9 to 4.7</td>
<td>26</td>
<td>0.91</td>
<td>0.83 to 0.96</td>
<td>Excellent</td>
</tr>
<tr>
<td>Wrist extension strength left1</td>
<td>15.2</td>
<td>4.6</td>
<td>15.6</td>
<td>5.2</td>
<td>-0.4</td>
<td>1.9</td>
<td>-1.0 to 0.3</td>
<td>-4.1 to 3.3</td>
<td>24</td>
<td>0.93</td>
<td>0.86 to 0.96</td>
<td>Excellent</td>
</tr>
<tr>
<td>Purdue Pegboard right2</td>
<td>16.3</td>
<td>1.7</td>
<td>17.4</td>
<td>2.0</td>
<td>-0.7*</td>
<td>1.2</td>
<td>-2.0 to 3.0</td>
<td>-0.2 to 3.3</td>
<td>14</td>
<td>0.73</td>
<td>0.51 to 0.84</td>
<td>Moderate</td>
</tr>
<tr>
<td>Purdue Pegboard left2</td>
<td>14.9</td>
<td>2.1</td>
<td>15.9</td>
<td>2.0</td>
<td>-1.0*</td>
<td>1.1</td>
<td>-1.5 to 0.0</td>
<td>-2.6 to 0.7</td>
<td>12</td>
<td>0.76</td>
<td>0.57 to 0.87</td>
<td>Good</td>
</tr>
<tr>
<td>CMDT displacing right3</td>
<td>185.4</td>
<td>20.3</td>
<td>174.6</td>
<td>18.6</td>
<td>10.8*</td>
<td>8.4</td>
<td>5.7 to 13.7</td>
<td>13.7 to 27.3</td>
<td>8</td>
<td>0.77</td>
<td>0.56 to 0.88</td>
<td>Good</td>
</tr>
<tr>
<td>CMDT displacing left3</td>
<td>206.6</td>
<td>20.2</td>
<td>189.8</td>
<td>20.7</td>
<td>10.8*</td>
<td>11.2</td>
<td>6.6 to 14.6</td>
<td>-11.2 to 32.8</td>
<td>11</td>
<td>0.73</td>
<td>0.53 to 0.86</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Mean 1: group mean in the first session; Mean 2: group mean in the second session; ICC: Intraclass Correlation Coefficient (one-way random model); 95%CI: 95% confidence interval; Sd: standard deviation; ψ: ratio between limits of agreement and mean score x 100%; 1: kilograms; 2: number of pins placed; 3: seconds; *Significant (one tailed) at p< 0.01; ** Significant (two tailed) at p<0.05.
A repeated measures design showed that within the three trials of the PP and the four trials of the CMDT, a significant (p < 0.01) learning effect was present (Table 3). A significant decline in handgrip strength tests between trials was also present in positions 2 and 3 (Table 3). Additionally, the results of reliability of male and female, and the youngest 50th percentile and the oldest 50th percentile of the participants are presented in appendix 2. Men and women had lower ICCs when calculated separately (mean ICC = 0.85 and 0.74 respectively). For the youngest 50th percentile (mean age was 23.1 ± 1.8 yr), ICCs of repetitive reaching, the PP and the CMDT all were below the 0.75 level.

### Discussion

The test-retest reliability determines the consistency of measures or scores from one testing occasion to another [5]. Test-retest reliability was expressed by Intraclass Correlation Coefficients (ICCs). An ICC is a ratio measure of the between-subject variance and the within-subject variance. A high ICC represents a relatively high between-subject variance. 95% Limits of agreement were calculated as a descriptive measure of agreement. 95% Of the differences between the two tests lies within this interval since all tests were approximately normally distributed [2]. To avoid bias the test-retest intervals must be far enough apart to

---

**Table 3. Intertrial effects of wrist, hand and finger strength, the Purdue Pegboard Task and the CMDT for the first test session.**

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>F value (df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handgrip strength position 1 right^1</td>
<td>29.0</td>
<td>31.5</td>
<td>30.9</td>
<td></td>
<td>6.3 (1,32)*</td>
</tr>
<tr>
<td>Handgrip strength position 1 left^1</td>
<td>29.5</td>
<td>29.8</td>
<td>29.4</td>
<td></td>
<td>0.1 (1,32)</td>
</tr>
<tr>
<td>Handgrip strength position 2 right^1</td>
<td>42.7</td>
<td>42.5</td>
<td>41.4</td>
<td></td>
<td>2.1 (1,32)</td>
</tr>
<tr>
<td>Handgrip strength position 2 left^1</td>
<td>39.7</td>
<td>38.2</td>
<td>37.1</td>
<td></td>
<td>3.5 (2,31)*</td>
</tr>
<tr>
<td>Handgrip strength position 3 right^1</td>
<td>39.8</td>
<td>38.9</td>
<td>38.9</td>
<td></td>
<td>5.0 (1,32)*</td>
</tr>
<tr>
<td>Handgrip strength position 3 left^1</td>
<td>36.0</td>
<td>35.2</td>
<td>33.2</td>
<td></td>
<td>20.3 (1,32)**</td>
</tr>
<tr>
<td>Handgrip strength position 4 right^1</td>
<td>35.5</td>
<td>33.7</td>
<td>33.0</td>
<td></td>
<td>6.2 (2,31)*</td>
</tr>
<tr>
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<td>28.8</td>
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<td>2.1 (1,32)</td>
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<tr>
<td>Handgrip strength position 5 left^1</td>
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<td>25.6</td>
<td>25.0</td>
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<td>3.5 (2,31)*</td>
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<td>5.1</td>
<td>5.4</td>
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<tr>
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<td>5.1</td>
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<td>7.6</td>
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<td>1.7 (1,32)</td>
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<td>7.4</td>
<td>7.2</td>
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<td>0.7 (1,30)</td>
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<tr>
<td>Key pinch strength right^1</td>
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<td>9.0</td>
<td>9.1</td>
<td></td>
<td>1.4 (1,32)</td>
</tr>
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<td>2.0 (2,29)</td>
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<tr>
<td>Wrist extension right^1</td>
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<tr>
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<td>15.4</td>
<td>15.4</td>
<td>14.9</td>
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<td>2.6 (1,32)</td>
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<td>Purdue Pegboard Task right^2</td>
<td>16.1</td>
<td>16.6</td>
<td>17.3</td>
<td></td>
<td>19.8 (1,32)**</td>
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<td>15.0</td>
<td>15.4</td>
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<td>18.2 (1,32)**</td>
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<tr>
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<td>48.7</td>
<td>46.4</td>
<td>46.0</td>
<td>44.2</td>
<td>59.6 (1,32)**</td>
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<tr>
<td>Complete Minnesota Dexterity Test left</td>
<td>52.8</td>
<td>50.6</td>
<td>50.1</td>
<td>48.4</td>
<td>19.1 (3,30)**</td>
</tr>
</tbody>
</table>

*df: degrees of freedom; ^1: kilograms; ^2: number of pins placed; ^3: seconds; * F-value is significant at p< 0.05; ** F-value is significant at p< 0.01.

---

Test-retest reliability of a WRULD FCE in healthy subjects
avoid fatigue, and close enough to avoid genuine changes in performance. In this study there was a 10 day time interval. Tests were performed on three different locations. This may have affected reliability scores, because it is not known whether testing on different locations results in different scores. In one location, weights of the overhead lifting test were different. Instead of using weights of 1.0, 2.0 and 4.0 kg, weights of 2.5 and 5.0 kg were used. The results of the overhead lift however, are probably not affected because the ICCs in previous studies [3,13] correspond with the ICC in this study. It appears that testing on different locations did not influence the test scores. The overhead worktest was modified from the original IWS procedure protocol because previous studies found an unacceptable reliability and because the test had a ceiling at 15 minutes. Therefore, two cuffweights of each 1.0 kg were worn around the subject’s forearm. This led to an increase in ICC from 0.58 [13] to 0.90, resulting in an excellent reliability of the overhead worktest and a decreased holding time, from a mean of 375 to a mean of 230 seconds. For wrist extension strength, a self-designed prototype was used to measure maximal static wrist extension strength. ICCs show excellent reliability for both hands (0.91 right and 0.93 left). For handgrip strength it is known that most force can be produced in positions 2 and 3 because of the biomechanical difficulty of producing force at the widest and narrowest positions [6,15]. ICCs of tests in positions 2 to 5 show excellent reliability (ICC > 0.90). The tests repetitive reaching right, the PP right and the CMDT left show ICCs of respectively 0.74, 0.73 and 0.73. This means that, based on the statistical criteria (ICC), reliability is moderate. Despite this, the limits of agreement of these tests all ranged between ±15% of the mean score and therefore were small enough to be considered reliable. Based on the ICCs and limits of agreement it is concluded that all 26 test items of the WRULD FCE are reliable.

Learning effects were significant (p < 0.01) in the Purdue Pegboard Task and in the Complete Minnesota Dexterity Test. It was hypothesized that this learning effect would decline after removing the first trial from analyses. Post hoc t-tests, however, show that the learning effect was still present, after removing the first trial from analyses. Participants were still significantly faster on the retest than on the first test after removing the first trial and ICCs also did not increase relevantly. A significant learning effect in the two coordination tasks may contribute to a lower reliability coefficient. Repeated measures for within trials for wrist and finger strength show that a decline of strength was significantly present in the hand grip tests (Table 3). Innes [6] reported a study in which a pattern of decline in grip strength related to intertrial rest periods was found across five trials. The longest intertrial rest period had a significantly smaller percentage of decline from the first to the last trial. Therefore, fatigue may have influenced the test results in this study, but the relevance of this decline is disputable, because the differences in measurement were small.

Gender differences were present in all strength tests and the PP. Men scored significantly higher on the overhead lift, hand, finger and wrist extension strength tests. This result complies with Mathiowetz et al. [10] who found significant
differences between males and females in grip and pinch strength. Women scored significantly higher on the PP. Gender differences were known to be present in the PP [14]. ICCs were lower for men and women when calculated separately than when calculated together (average ICC=0.74 for women and 0.85 for men vs. 0.86 for the whole group). This may be due to the small groups that remain after splitting. An additional median split was performed to control if the youngest 50th percentile and the oldest 50th percentile differ in ICCs. The old group had higher ICCs on the coordination tasks than the young group. Reliability was not acceptable for these tests in the young group. A small sample size might explain this. Further research on this area is needed to test the differences in reliability found in this study between age groups in a larger sample.

Conclusion

Test-retest reliability of 3 test items were moderate, of 9 test items good and of 14 test items excellent. Based on ICCs and limits of agreement all eight tests were reliable. It is concluded that the WRULD FCE is reliable in healthy adults and can be used for clinical measurement.

Acknowledgements

The authors thank employees of UMCG Department of Work and Health and UC Promotions for voluntarily participating in this study.

References

Chapter 4

16. Lafayette Instrument. Purdue Pegboard Model #32020: instructions and normative data.

**Appendix 1: Materials, Objectives and Procedures of the WRULD FCE**

**The overhead lift**
Objective: functional strength of shoulder and arm musculature. Materials: plastic receptacle (40 x 30 x 26 cm). A wall mounted system with adjustable shelves and weights of 1.0, 2.0 and 4.0 kilograms (kg). Procedure: 5 lifts from table to crown height v.v. within 90 seconds in standing position. 4 to 5 weight increments were used until maximum amount of weight was reached.

**The overhead worktest**
Objective: static holding time of shoulder and neck musculature. Materials: aluminum plate adjustable in height with 18 holes, bolts and nuts and 2 cuff-weights of 1.0 kg each. Procedure: standing with hands at crown height,
manipulating nuts and bolts wearing cuff weights around the forearms. The time that position is held is measured (sec).

**Repetitive reaching**
Objective: fast repetitive movements of the upper extremity. Materials: 30 marbles and two bowls with a 14 cm diameter. Procedure: sitting with bowls on wing span, remove marbles horizontally at table height from left to right v.v. with left/right arm. Time needed to remove 30 marbles is scored (sec).

**Handgrip strength**
Objective: isometric grip strength. Materials: a hand dynamometer (Jamar PC 5030, Preston Corporation, 1994). Procedure: in a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90 degrees and the forearm and wrist in neutral position [5]. Grip strength of the right and left arm was measured in a three-trial procedure in five different handgrip positions (10 test items). Average amount of kgF was scored.

**Finger strength**
Objective: isometric tip, key and palmar pinch strength. Materials: a pinch-grip dynamometer (Preston Pinch Gauge; J.A. Preston Corporation). Procedure: In a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90 degrees, the forearm horizontally pronated and wrist in neutral position [5]. Strength of right and left fingers was measured in a three-trial procedure (6 test items). Average amount of weight was scored.

**Wrist extension strength**
Objective: isometric wrist extension strength. Materials: a dynamometer (type Chatillon, CSD 200) and a self designed apparatus to fix the dynamometer in a vertical position above the wrist. Procedure: wrist was fixed with the forearm horizontally pronated and wrist in neutral position. The dynamometer measured wrist strength of the left and right arm perpendicular and directly proximal to the third caput metacarpale. Average amount of weight was scored over three trials.

**Fingertip dexterity test**
Objective: fingertip dexterity. Materials: Purdue Pegboard (Model #32020, Lafayette IN.). Procedure: sitting subject in front of the pegboard, placing pins with left and right hand as fast as possible in a 30 sec trial. Average number of pins placed in 30 sec. over three trials for both hands was scored [16].

**Hand and forearm dexterity test**
Objective: gross movement coordination of fingers, hands and arms. Materials: a Complete Minnesota Dexterity Test (Lafayette IN.). Procedure: sitting subject displacing 59 blocks in a pre-determined way as fast as possible. Total displacing time needed to perform 4 trials for both hands was scored [17].
### Appendix 2. Intraclass Correlation Coefficients and 95% Confidence Intervals of men and women apart of the youngest and oldest 50th percentile.

<table>
<thead>
<tr>
<th>Test</th>
<th>ICC men</th>
<th>95% CI</th>
<th>ICC women</th>
<th>95% CI</th>
<th>ICC of youngest</th>
<th>95% CI</th>
<th>ICC of oldest</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead lift</td>
<td>0.88</td>
<td>0.68 to 0.95</td>
<td>0.68</td>
<td>0.34 to 0.87</td>
<td>0.90</td>
<td>0.77 to 0.96</td>
<td>0.93</td>
<td>0.80 to 0.98</td>
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<tr>
<td>Overhead worktest</td>
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<td>0.87</td>
<td>0.69 to 0.95</td>
<td>0.84</td>
<td>0.65 to 0.93</td>
<td>0.96</td>
<td>0.87 to 0.99</td>
</tr>
<tr>
<td>Repetitive reaching right</td>
<td>0.72</td>
<td>0.34 to 0.90</td>
<td>0.74</td>
<td>0.44 to 0.89</td>
<td>0.61</td>
<td>0.26 to 0.83</td>
<td>0.78</td>
<td>0.43 to 0.93</td>
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<td>0.60</td>
<td>0.15 to 0.85</td>
<td>0.83</td>
<td>0.61 to 0.93</td>
<td>0.63</td>
<td>0.28 to 0.83</td>
<td>0.83</td>
<td>0.54 to 0.94</td>
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<td>0.61 to 0.93</td>
<td>0.88</td>
<td>0.73 to 0.95</td>
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<td>Handgrip strength position 1 left</td>
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<td>0.47 to 0.93</td>
<td>0.80</td>
<td>0.56 to 0.92</td>
<td>0.92</td>
<td>0.82 to 0.97</td>
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<td>0.60 to 0.95</td>
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<tr>
<td>Handgrip strength position 2 right</td>
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<td>0.81</td>
<td>0.58 to 0.92</td>
<td>0.94</td>
<td>0.86 to 0.98</td>
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<td>0.89 to 0.99</td>
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<th>ICC women</th>
<th>95% CI</th>
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<th>95% CI</th>
<th>ICC of oldest*</th>
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<td>0.92</td>
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<td>0.39 to 0.89</td>
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<td><strong>0.84</strong></td>
<td><strong>0.87</strong></td>
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</tbody>
</table>

*ICC: Intraclass Correlation Coefficient (one-way random model), 95%CI: 95% Confidence Interval; CMDT: Complete Minnesota Dexterity test, *: median split at 50th percentile.*
Chapter 5

Pain Response of Healthy Workers Following a Functional Capacity Evaluation and Implications for Clinical Interpretation

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