Chapter 7

Development and reliability of the rating of compensatory movements in upper limb prosthesis wearers during work related tasks

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Submitted
Abstract

Purpose 1) To develop a qualitative scoring system for rating compensatory shoulder and trunk movements in upper limb prosthesis wearers during the performance of functional capacity evaluation tests adjusted for the use in one handed individuals (FCE-OH), 2) to examine the inter- and intrarater reliability and 3) the feasibility of the scoring system.

Methods Movement patterns of 12 videotaped upper limb prosthesis wearers and 20 controls were analysed. Compensatory movements were defined for each FCE-OH test, and a scoring system was developed, pilot tested and adjusted. During reliability testing 18 raters (12 FCE-experts and 6 physiotherapists/gait analysts) scored video recordings of upper limb prosthesis wearers and controls, each performing 4 FCE-OH tests two times (two weeks apart). Agreement was expressed in % and Kappa value. Feasibility was determined by using a questionnaire.

Results After 2 rounds of pilot testing and adjusting, reliability of a third version was tested. The interrater reliability for the first and second rating sessions were κ=0.54 and κ=0.64, respectively. The intrarater reliability was κ=0.77. The feasibility was good, but could be improved by a short training program.

Conclusion A scoring system was developed to assess compensatory movements in upper limb prosthesis wearers during the performance of FCE-OH tests. Interrater reliability was satisfactory in most instances, intrarater reliability was good. Feasibility was established.
Introduction

People with upper limb absence (ULA), either caused by congenital deficiency or by an amputation, need to make compensatory movements with both arms (affected and unaffected) and with their trunk in order to perform daily tasks and work-related tasks with their prosthesis.\textsuperscript{1,2} They need to compensate for the loss of wrist, forearm (pronation and supination) and sometimes elbow movements, due to limited degrees of freedom of the prosthesis.\textsuperscript{2} Prosthesis wearers compensate the most with their trunk and shoulders,\textsuperscript{1,2} however the compensatory movements seem to be task-specific.\textsuperscript{1,124} Compensatory movements have not yet been studied during execution of work-related tasks in this patient group.

Compensatory movements may cause musculoskeletal complaints (MSC) due to overuse or increased physical load on the affected or the unaffected arm, neck and back.\textsuperscript{5,7,8} It is known that the prevalence of neck, back and (un)affected arm complaints in individuals with ULA is twice as high in comparison with the general population: 57% compared to 29%, respectively.\textsuperscript{91} In patients with ULA non-physical risk factors related to MSC have been identified; such as middle age, being divorced or widowed and lower mental health,\textsuperscript{91} but physical risk factors have not yet been identified. In the general population physical risk factors for MSC are working in awkward positions, static muscle contractions and forceful and repetitive movements.\textsuperscript{94} MSC can affect the quality of life and participation in social roles such as work,\textsuperscript{5,7,8,125} and individuals with ULA are mostly young and have many potential working years.\textsuperscript{5}

Quantifying compensatory movements during work-related tasks may help professionals to guide them in developing their treatment plan. Furthermore, such a quantification may contribute to predicting the risk on MSC in individuals with ULA and may give insight into preventive measures to preclude MSC. To our knowledge there is currently no system that systematically scores compensatory movements in patients with ULA during execution of work-related tasks. In rehabilitation and occupational medicine a functional capacity evaluation (FCE), which is a comprehensive test containing work-related tasks,\textsuperscript{94} is used to measure functional capacity, to assess disabilities, to monitor the progress of rehabilitation and guide return to work recommendations.\textsuperscript{94,95,126} Recently our research group developed the FCE One Handed (FCE-OH), which is a short-form FCE adjusted for one-handed individuals and prosthesis users. The FCE-OH consists of six FCE tests; the overhead work test, the repetitive reaching test, the fingertip dexterity test, the overhead lifting test-two handed, overhead lifting test-one handed and hand grip strength test.

The score of FCE tests is a quantitative score, for example how much weight an individual can lift or how fast he can complete a task. However, a quantitative score does not help a therapist to get insight into compensatory movements. A qualitative assessment of compensatory movements during FCE could be useful for therapy and return to work.
recommendations. Compensatory movements can be assessed in several ways, including observation.\textsuperscript{127} Observational scales are already used in FCEs to determine the level of physical effort during FCE tests,\textsuperscript{126} but a qualitative scoring system for compensatory movements is lacking. This study aimed 1) to develop a qualitative scoring system for rating compensatory shoulder and trunk movements in upper limb prosthesis wearers during the performance of FCE-OH tests by observation, 2) to examine the inter- and intrarater reliability and 3) to examine the feasibility of the scoring system.

**Methods**

**Design**

The scale development and testing consisted of five phases: planning, construction phase 1, qualitative evaluation phase 1, construction phase 2, and qualitative evaluation phase 2. The scoring system is developed in the first four phases, while in qualitative evaluation phase 2 the inter- and intrarater reliability were examined, as well as feasibility.

**Ethics**

This study was approved by the Medical Ethics Committee of the UMCG (NL433394.042.13). All participants provided written informed consent before entering the study.

**Participants**

There were four types of participants in this study; pilot-testers, observers, patients and controls:

**Pilot-testers (observers during construction phase 1 and 2)** In the first construction phase three groups, each consisting of seven raters with a medical background, but without FCE-experience, participated in the pilot-tests. For pilot testing in the second construction phase five international FCE-experts were recruited among participants of an international FCE research meeting.\textsuperscript{128}

**Observers (observers during qualitative evaluation phase 1 and 2)** During qualitative evaluation phase 1 four FCE experts from the Netherlands participated. In qualitative evaluation phase 2 two groups of raters were involved: (I) 12 (inter)national FCE experts from Canada, the Netherlands, United States of America and South Africa (mean years of FCE-experience 16.3±10.5), were recruited among participants of an international FCE research meeting\textsuperscript{128} (different individuals from those participating in construction phase 2), and (II) a convenience sample of six physiotherapists/gait analysts (mean years of professional experience 7.7±8.7 years), without FCE-experience, from the rehabilitation department of the UMCG.
Patients Inclusion criteria for prosthesis wearers were: a normal function of their sound hand and at least one year experience of prosthesis use. Prosthesis wearers were recruited via a questionnaire used for another study, in which they all declared to be interested in follow-up research. All prosthesis wearers (three females, nine males, mean age 46.8±11.5 years, mean time of prosthesis use 30.5±17.2 years) had an amputation or congenital deficiency at transradial or wrist disarticulation level.

Controls Inclusion criteria for controls were no joint, muscle or nerve disorders and a normal hand function in both hands. Exclusion criteria for patients and controls were invalidating or serious health conditions that might influence the results of the FCE. These conditions were analysed by using the Physical Activity Readiness Questionnaire (PAR-Q). Via advertisements 21 able-bodied controls (three females, 18 males, mean age 45.8±11.7 years) were recruited.

Video recordings of 12 upper limb prosthesis wearers and 21 able-bodied controls performing four FCE-OH tests (Text box 1) were taken at the University Medical Centre Groningen (UMCG) in 2014.

Tests
Four out of six FCE-OH tests were selected. No compensatory movements were expected in the overhead lifting test one-handed and the hand grip strength test, since both test are one-handed and performed with the unaffected side (Text box 1).

Four phases of scale development
The development of the qualitative scoring system was based on the four phases described in the guide for instrument development and validation of Benson and Clark. Planning, construction, qualitative evaluation and validation. In this study the first three phases were completed (Figure 1). The construction and qualitative evaluation phases were repeated if insufficient results were obtained after reliability testing. In the planning phase compensatory movements were listed by four medical professionals who compared the movement patterns of videotaped prosthesis wearers with the movement patterns of videotaped healthy controls. A compensatory movement was defined as a movement different from the control group. In the first draft compensatory movements were categorised as subtle or strong compensatory movements. A movement was defined as strong compensatory movement when there was a large difference from the movement pattern of the control group; smaller differences were defined as subtle compensatory movements. In construction phase 1 the first draft of the scoring system was pilot tested and adjusted in three rounds till the interrater kappa values of all items were >0.6. The adjustments were based on feedback of the 21 pilot-testers (Figure 1). During pilot testing it became clear that differentiation between no compensation, subtle and strong compensatory movements was unfeasible. Based on the feedback of the pilot-testers the categories “no compensation” and “subtle compensation” were combined. In
qualitative evaluation phase 1 the inter- and intrarater reliability of this first draft was determined by four FCE experts. Since the interrater and intrarater reliability of half of the items needed improvement, a second construction phase was performed using the feedback provided by the FCE experts in the previous phase. The improved scoring system was pilot tested online by five international FCE experts, using a video fragment rating system (a secure online video streaming service). The use of the scoring system was explained by a video instruction.

After this developmental process the observational scoring system consisted of eight items; two items per FCE-OH test (Appendix 1).

**Text box 1** FCE-objectives, instruction to the participants, quantitative FCE-outcome and the used camera position per FCE task.

<table>
<thead>
<tr>
<th>Test</th>
<th>Objective</th>
<th>Instruction</th>
<th>FCE-outcome</th>
<th>Camera position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead lift test</td>
<td>To test the strength of shoulder and arm musculature</td>
<td>Lift the plastic receptacle containing weights from table height to crown height 5 times within 90 seconds. The start weight is 2 kg for women and 4 kg for men. After every 5 lifts weights of 2 kg for women and 4kg for man are added until the maximum weight is reached.</td>
<td>The maximum lifted weight</td>
<td>Behind the participant</td>
</tr>
<tr>
<td>Repetitive reaching test</td>
<td>To test fast repetitive reaching movements of the upper extremity</td>
<td>Sit between two clicking systems on wing span and alternate clicking each button for a total of 30 times</td>
<td>Time needed to press each buttons 15 times</td>
<td>In front of the participant</td>
</tr>
<tr>
<td>Fingertip dexterity test</td>
<td>To test fingertip dexterity</td>
<td>Sit in front of the pegboard and place the pins in the board as fast as possible.</td>
<td>The number of pins placed in the board in 30 seconds</td>
<td>In front of the participant</td>
</tr>
<tr>
<td>Overhead work test</td>
<td>To test the static holding time of shoulder and neck musculature</td>
<td>Stand with the hands on crown height and manipulate nuts and bolts wearing a cuff weight around the unaffected wrist</td>
<td>Time the position is held</td>
<td>Behind the participant</td>
</tr>
</tbody>
</table>
Development and reliability of the rating of compensatory movements

Figure 1 Flowchart of the method used in the development of the observational scoring system for scoring compensatory movements in prosthesis wearers during the performance of FCE-OH tests, including the final phase of reliability and feasibility testing.

**Planning phase**
- Define the goal: Development of a scoring system for rating compensatory movements of upper limb prosthesis wearers
- List compensatory trunk and shoulder movements from video recordings

**Construction phase 1 Development and pilot testing of the scoring system**
- Construct first draft of scoring system
- Pilot testing till interrater $\kappa$>0.6 for all items: in total 3 pilot tests (pilot 1a, b, and c) were performed
  - Medical professionals/students without FCE-experience (n=7 per pilot test) performed 1 session
  - After each pilot items were adjusted based on feedback of the raters and kappa-values

**Qualitative evaluation phase 1 Inter- and intrarater reliability testing**
- Pilot test 2: FCE-experts (n=4) performed 2 rating sessions, 2 weeks apart
- Feedback: raters provided feedback after the second rating session
- Results: interrater $\kappa$<0.6 for 3/8 items, intrarater $\kappa$<0.6 for 4/8 items

**Construction phase 2 Adjustments since results qualitative evaluation phase 1 were insufficient**
- Adjustment of items with $\kappa$<0.6 based on the feedback of the raters of qualitative evaluation phase 1
- Pilot test 3: FCE-experts (n=5) performed 1 rating session, using an online video instruction
- Results: $\kappa$<0.6 for 4/8 items, small adjustments were made based on the feedback of the raters

**Qualitative evaluation phase 2 Inter- and intrarater reliability and feasibility testing**
- FCE-experts (n=12) and physiotherapists/gait analysists (n=6) performed 2 rating sessions, 2 weeks apart
- Results presented in Table 1

$K =$ Cohen’s kappa; $\kappa$>0.6 was considered sufficient.
Fifth phase: qualitative evaluation phase 2

Inter- and intrarater reliability testing Two groups of raters performed two rating sessions, two weeks apart. Before each session the use of the observational scoring system was explained by a video instruction, which was previously used in construction phase 2. Subsequently raters had to score four video recordings, each with a duration of 20 seconds per item of the scoring system. The raters reviewed the two items per FCE-OH test separately. Raters were instructed to perform the rating without consulting colleagues. The first group of raters (FCE-experts) were not supervised; they performed the rating sessions online, using video fragment ratings and were instructed to remove their rating from their computer after the first rating session. The second group of raters (physiotherapists/gait analysts) performed both rating sessions with supervision of a researcher and had to hand in their ratings after the first rating session.

Feasibility After the performance of the second rating session raters gave feedback, using a short questionnaire containing questions about the applicability and the (dis)advantages of the developed scoring system.

Statistical analysis During pilot testing Cohen’s Kappa (\(\kappa\)) for multiple raters was used to analyse interrater reliability per item. Reliability was considered sufficient if \(\kappa>0.6\). Items were adjusted if \(\kappa \leq 0.6\). Kappa was used to determine the inter- and intrarater reliability of the final scale. The intrarater reliability was determined for both rating sessions. Reliability was considered sufficient if kappa values were \(>0.6\), moderate when \(0.4<\kappa<0.6\), and poor when \(\kappa \leq 0.4\).\(^{130}\) ONLINE KAPPA CALCULATOR was used to analyse kappa for multiple raters.\(^{131,132}\) All other analyses were performed using Statistical Package for the Social Sciences (SPSS) version 22.0 software package (SPSS; IBM, Armonk, NY).

Results

Qualitative evaluation phase 2

Inter- and intrarater reliability testing In total 18 raters performed both rating sessions. Mean time between first and second rating session was 14.4±1.0 days. Results of reliability testing are presented in Table 1. The overall intrarater reliability was considered moderate in the first rating session (\(\kappa=0.54\), 95% CI 0.52-0.57) but sufficient in the second rating session (\(\kappa=0.64\), 95% CI 0.61 to 0.66). The overall intrarater reliability was considered good (\(\kappa=0.71\), 95% CI 0.72 to 0.82). The overall kappa values of physiotherapist/gait analysts were similar to the overall kappa scores of FCE-experts. The latter also implies that unsupervised scoring as performed by the FCE experts leads to...
comparable results as supervised scoring, as performed by the physiotherapists/gait analysts, although a trend for higher scores in the supervised group was seen.

### Table 1 Inter- intrarater reliability of the developed scoring system.

<table>
<thead>
<tr>
<th></th>
<th>Intrarater reliability 1st session</th>
<th>Intrarater reliability 2nd session</th>
<th>Intrarater reliability</th>
<th>Overall FCE experts</th>
<th>Overall physiotherapist</th>
<th>Overall FCE experts and physiotherapist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>κ (%)</td>
<td>95% CI</td>
<td>k (%)</td>
<td>95% CI</td>
<td>k (%)</td>
<td>95% CI</td>
</tr>
<tr>
<td><strong>Overhead work test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosthesis side</td>
<td>0.53 (79%)</td>
<td>0.46; 0.61</td>
<td>0.71 (87%)</td>
<td>0.63; 0.79</td>
<td>0.75 (88%)</td>
<td>0.59; 0.91</td>
</tr>
<tr>
<td>Unaffected side</td>
<td>0.40 (74%)</td>
<td>0.32; 0.48</td>
<td>0.56 (81%)</td>
<td>0.48; 0.64</td>
<td>0.65 (85%)</td>
<td>0.45; 0.84</td>
</tr>
<tr>
<td><strong>Repetitive reaching test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaching</td>
<td>0.60 (81%)</td>
<td>0.52; 0.68</td>
<td>0.73 (87%)</td>
<td>0.65; 0.80</td>
<td>0.79 (90%)</td>
<td>0.65; 0.94</td>
</tr>
<tr>
<td>Press the button</td>
<td>0.43 (71%)</td>
<td>0.35; 0.51</td>
<td>0.44 (72%)</td>
<td>0.36; 0.52</td>
<td>0.67 (83%)</td>
<td>0.50; 0.84</td>
</tr>
<tr>
<td><strong>Fingertip dexterity test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm movements</td>
<td>0.84 (91%)</td>
<td>0.76; 0.92</td>
<td>0.82 (95%)</td>
<td>0.82; 0.97</td>
<td>0.97 (97%)</td>
<td>0.92; 1.03</td>
</tr>
<tr>
<td>Trunk movements</td>
<td>0.12 (75%)</td>
<td>0.04; 0.20</td>
<td>0.06 (74%)</td>
<td>-0.02; 0.14</td>
<td>0.50 (86%)</td>
<td>0.47; 0.53</td>
</tr>
<tr>
<td><strong>Overhead lift test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm movements</td>
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<td>0.43; 0.59</td>
<td>0.74 (87%)</td>
<td>0.66; 0.82</td>
<td>0.75 (88%)</td>
<td>0.60; 0.90</td>
</tr>
<tr>
<td>Trunk movements</td>
<td>0.27 (69%)</td>
<td>0.19; 0.35</td>
<td>0.23 (73%)</td>
<td>0.15; 0.31</td>
<td>0.72 (94%)</td>
<td>0.54; 0.90</td>
</tr>
<tr>
<td>Overall FCE experts</td>
<td>0.54 (75%)</td>
<td>0.52; 0.57</td>
<td>0.66 (81%)</td>
<td>0.63; 0.69</td>
<td>0.75 (88%)</td>
<td>0.68; 0.82</td>
</tr>
<tr>
<td>Overall physiotherapist</td>
<td>0.60 (77%)</td>
<td>0.49; 0.70</td>
<td>0.72 (86%)</td>
<td>0.61; 0.83</td>
<td>0.84 (82%)</td>
<td>0.75; 0.92</td>
</tr>
<tr>
<td>Overall FCE experts and</td>
<td>0.54 (77%)</td>
<td>0.52; 0.57</td>
<td>0.64 (82%)</td>
<td>0.61; 0.66</td>
<td>0.71 (89%)</td>
<td>0.72; 0.82</td>
</tr>
<tr>
<td>physiotherapist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*NOTE: κ (%): Cohen’s kappa (percentage of absolute agreement); 1st session: first rating session; 2nd session: second rating session.*

* The ratings of one rater were omitted from analysis due to missing data.

**Feasibility** Eight out of twelve FCE-experts and six physiotherapists/gait analysts provided feedback on the scoring system. All raters stated that the system was easy to apply and could be used easily in clinical practice. Twelve raters stated that the developed scoring system may provide clinicians with useful additional information for the assessment and treatment of upper limb prosthesis wearers, two raters were neutral. Standardization of assessing compensatory movements and easiness to use the scoring system were regarded to be important advantages. Ten raters suggested a short training program containing more examples of compensatory movements might improve the scoring system further.
Discussion

A qualitative scoring system for rating compensatory shoulder and trunk movements in upper-limb prosthesis wearers during the performance of FCE-OH tests was developed following the guideline for instrument development. The intrarater reliability of the scoring system was good. The interrater reliability of the first rating session was insufficient, but sufficient in the second session. Feasibility of the rating system was established, a short training program explaining the use of the scoring system was recommended.

The results show that it seems to be possible to identify compensatory movements reliably by observation using a dichotomous observational scoring system. The current version of the developed scoring system does not rate subtle compensatory movements, since pilot testing revealed that differentiation between subtle and strong compensatory movements was unfeasible. As such, the current scale can be used by clinicians to observe and rate larger compensatory movements. We expect that when raters have gained experience with applying the qualitative scoring system, scoring more subtle compensation strategies should be possible. Then, the system should be extended with a rating scale for advanced raters, and tested subsequently.

The interrater reliability increased over the first and second reliability tests, which is similar to the development of an FCE physical effort scale, suggesting a learning effect. Raters mentioned they were accustomed to assess compensatory movements of the entire body and now they had to focus on compensatory movements of a certain body part. A short training program is expected to further increase reliability.

The intrarater kappa values of the trunk movement item of the fingertip dexterity test were unexpectedly low (1st session $\kappa=0.12$, 2nd session $\kappa=0.06$) compared to the percentage of absolute agreement (1st session: 75%, 2nd session: 74%). This may be explained by an uneven cell filling. In our sample the total of the column “compensation” is higher than the total of the column “no compensation”, causing a high expected percentage of agreement and therefore low kappa values. A more balanced distribution of the scores may be obtained by rating more video recordings per item.

No differences were expected in interrater and intrarater overall kappa values of physiotherapist/gait analysts and FCE-experts, since both groups of raters did not have any specific experience in observing compensatory movements, other than might be expected due to their respective professions. We concluded that supervised or unsupervised ratings seem to lead to comparable results, although a trend for better results was seen in the supervised group of physiotherapists/gait analysists. We expect the results of unsupervised raters to improve further if a short training program is provided.
Not all compensatory trunk and shoulder movements may have been observed during the planning phase of scale development due to three reasons. Compensatory movements were defined as movement patterns different from the movement pattern of controls. It may be possible that controls used compensatory movements as well and that compensatory movements of prosthesis wearers were not recognized. Also low numbers of available video recordings of upper limb prosthesis wearers may have prohibited the occurrence of other compensatory movements. Furthermore, the participants were videotaped in one plane; compensatory movements made in other planes may have been missed. The relevance of missing these subtle compensations is unknown at present, and should be subject of further (validation) study. A final limitation is the sometimes suboptimal quality of the videos used in this study, which could have influenced the results of the qualitative evaluation phases. Due to insufficient standardized camera positions optical distortion occurred in half of the videos, which limited the number of videos suitable for rating. In order to standardize the camera position in future research it is proposed that the horizontal centre of the image should be at shoulder height and that the spine should be in the vertical centre of the image.

Before the scoring system could be used in practice, the reliability should be established by rating the performance of participants in real time. Furthermore the validity of the developed scoring system, which is step four in instrument development, needs to be tested.

Conclusion

A scoring system was developed to assess compensatory movements in upper limb prosthesis wearers during the performance of FCE-OH tests by observation. The scoring system was tested in the target population (FCE-experts and physiotherapists/gait analysts). The intrarater reliability was good and interrater reliability was satisfactory in the second rating session. The feasibility of the system was established and could be improved by a short training program before the use of the scoring system. Future research is needed to determine the reliability of the scoring system in clinical practice and to determine the validity of the developed scoring system.
Appendices

Appendix 1 Qualitative scoring system for scoring compensatory trunk and shoulder movements during the performance of FCE-OH tests.

**Overhead work test 1: Prosthesis side**

**POINTS OF ATTENTION:**
> Rate the *worst* performance
> Pay attention to the position of the elbow with respect to the shoulder

<table>
<thead>
<tr>
<th>No compensation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Example</td>
</tr>
</tbody>
</table>

![Example images](image)

**Prosthesis side**
- No compensation (0 point)
- Compensation (1 point)

**Overhead work test 2: Unaffected side**

**POINTS OF ATTENTION:**
> Rate the *worst* performance
> Pay attention to the position of the elbow with respect to the shoulder

<table>
<thead>
<tr>
<th>No compensation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Example</td>
</tr>
</tbody>
</table>

![Example images](image)

**Unaffected side**
- No compensation (0 point)
- Compensation (1 point)
Appendix 1 continued

Repetitive reaching test 1: Reaching

POINTS OF ATTENTION:

> Rate the worst performance
> Rate reaching with the prosthesis at the moment the arm moves in front of the body
> Pay attention at the height of the elbow with respect to the shoulder

<table>
<thead>
<tr>
<th>No/light compensation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example</strong></td>
<td><strong>Example</strong></td>
</tr>
</tbody>
</table>

The elbow moves under shoulder height in front of the body

The elbow moves at or above the height of the shoulder in front of the body

Repetitive reaching test 2: Press the button

POINTS OF ATTENTION:

> Rate the worst performance
> Rate internal rotation of the shoulder at the moment of pressing the button with the prosthesis. In case of internal rotation the elbow flexion crease turns downward (caudal) and the olecranon turns up (cranial)

<table>
<thead>
<tr>
<th>No compensation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example</strong></td>
<td><strong>Example</strong></td>
</tr>
</tbody>
</table>

No internal rotation of the shoulder when pressing the buttons

Internal rotation of the shoulder (the elbow flexion crease turns caudal and the olecranon turns cranial) when pressing at least one of the buttons

<table>
<thead>
<tr>
<th>Reaching</th>
<th>No or light compensation (0 point)</th>
<th>Compensation (1 point)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Internal rotation of the shoulder</th>
<th>No compensation (0 point)</th>
<th>Compensation (1 point)</th>
</tr>
</thead>
</table>
Appendix 1 continued

Fingertip dexterity test 1: Arm movements

POINTS OF ATTENTION:

> Rate the worst performance
> Rate at the moment of placement of the pin with the prosthesis in the board
> Pay attention the position of the elbow with respect to the shoulder

Fingertip dexterity test 2: Trunk movements

POINTS OF ATTENTION:

> Rate the worst performance
> Do rate at the moment of placement of the pin with the prosthesis in the board
> Pay attention the lateroflexion movements of the trunk

<table>
<thead>
<tr>
<th>Shoulder movements</th>
<th>No or light compensation (0 point)</th>
<th>Compensation (1 point)</th>
</tr>
</thead>
</table>

- The elbow stays under the height of the shoulder
- Elbow is lifted at or above the height of the shoulder

<table>
<thead>
<tr>
<th>Lateroflexion of the trunk</th>
<th>No or light compensation (0 point)</th>
<th>Compensation (1 point)</th>
</tr>
</thead>
</table>

- No or minimal lateroflexion movement of the trunk (<10°)
- Clear lateroflexion movement of the trunk (>10°)
Appendix 1 continued

**Overhead lift test 1: Arm movements**

**POINTS OF ATTENTION:**
> Rate the worst performance
> Rate the placement of the plastic receptacle at the top shelf

<table>
<thead>
<tr>
<th>No/light compensation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Example</td>
</tr>
</tbody>
</table>

Both elbows stay under or at the height of the shoulders
Minimal 1 elbow is lifted above the height of the shoulders

<table>
<thead>
<tr>
<th>Height of the elbows with respect to the shoulders</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No or light compensation (0 point)</td>
</tr>
<tr>
<td>□ Compensation (1 point)</td>
</tr>
</tbody>
</table>

**Overhead lift test 2: Trunk and scapula movements**

**POINTS OF ATTENTION:**
> Rate the worst performance
> Pay attention to:
  > Rotation of the trunk
  > Lateroflexion of the trunk
  > Symmetry of scapular movements
If one of these movements is persistent during the upward movement rate as compensation, ignore the downward movement

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
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</table>

No or minimal rotation or lateroflexion of the trunk AND symmetrical scapular movements
Lateroflexion and/or rotation of the trunk and/or asymmetrical scapular movements

<table>
<thead>
<tr>
<th>Trunk and scapula movements</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No or light compensation (0 point)</td>
</tr>
<tr>
<td>□ Compensation (1 point)</td>
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</tbody>
</table>