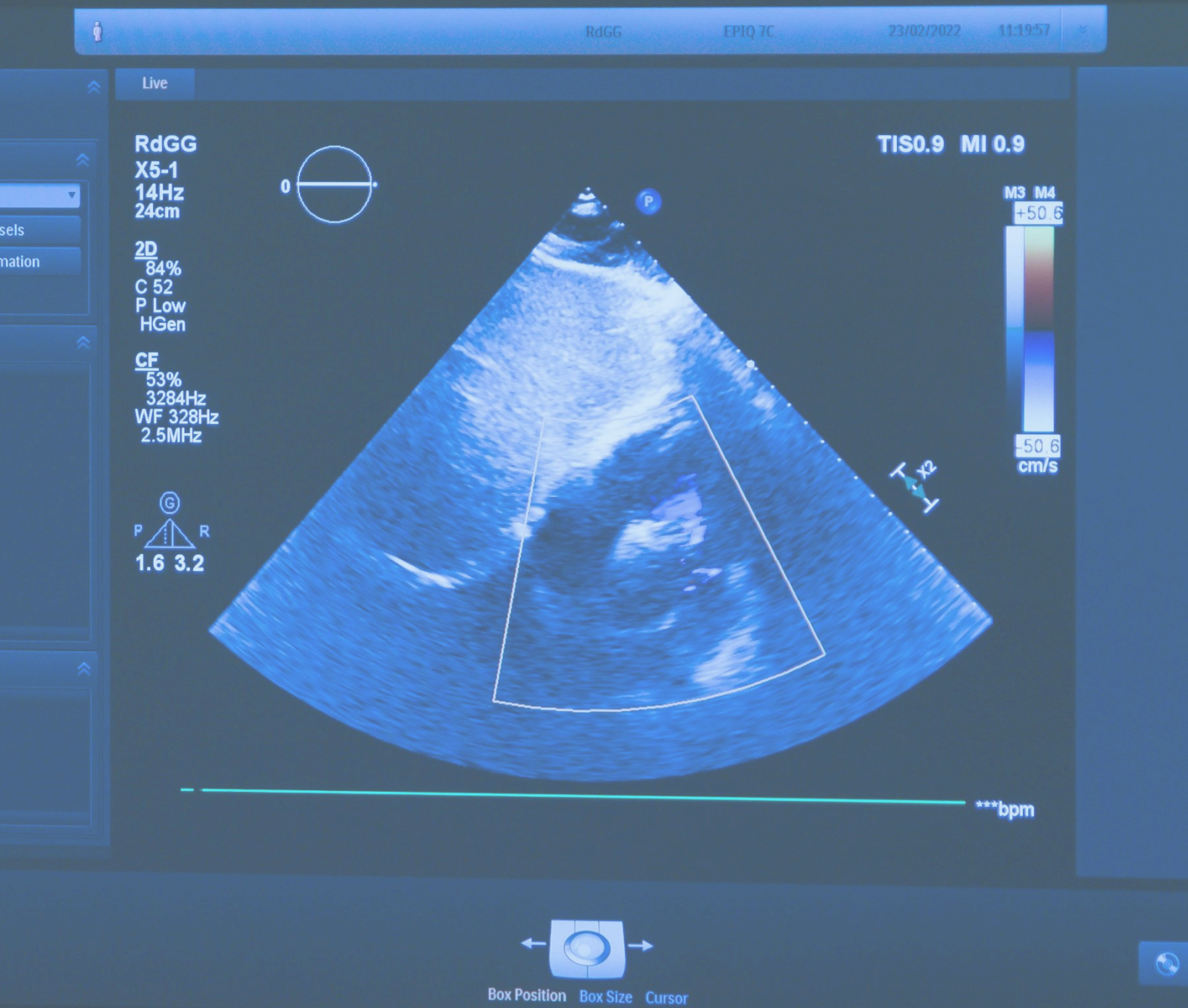


Appendix



SCHE INSTRUMENTATIE
arisnr: 46900
inier de Graaf
STORING TEL: 5808

1 2 3 4 5 6
MEDISCHE INSTRUMENTATIE
Volgende controle 2022
7 9 10 11 12

Appendix A: Informed Consent form document structure

Participant ID:

The prevention of work-related musculoskeletal disorders due to sonography practice

This research is conducted as part of the MSc study Industrial Design Engineering at TU Delft.

Informed consent participant

I participate in this research voluntarily.

I acknowledge that I received sufficient information and explanation about the research and that all my questions have been answered satisfactorily. I was given sufficient time to consent my participation. I can ask questions for further clarification at any moment during the research.

I am aware that this research consists of the following activities:

1. Fill in for specific activity (e.g. Interview, Observation, User Test)

I am aware that data will be collected during the research, such as notes, photos, video and/or audio recordings. I give permission for collecting this data and for making photos, audio and/or video recordings during the research. Data will be processed and analysed anonymously (without your name or other identifiable information). The data will only be accessible to the research team and their TU Delft supervisors.

The photos, video and/or audio recordings will be used to support analysis of the collected data. The video recordings and photos can also be used to illustrate research findings in publications and presentations about the project.

I give permission for using photos and/or video recordings of my participation:
(select what applies for you)

- ☐ in which I am recognisable in publications and presentations about the project.
- ☐ in which I am not recognisable in publications and presentations about the project.
- ☐ for data analysis only and not for publications and presentations about the project.

I give permission to store the data for a maximum of 5 years after completion of this research and using it for educational and research purposes.

I acknowledge that no financial compensation will be provided for my participation in this research.

With my signature I acknowledge that I have read the provided information about the research and understand the nature of my participation. I understand that I am free to withdraw and stop participation in the research at any given time. I understand that I am not obliged to answer questions which I prefer not to answer and I can indicate this to the research team.

The researchers take the applicable COVID-19 measures into account. I confirm to respect the COVID-19 measures taken and will follow instruction about these provided by the researchers.

I will receive a copy of this consent form.

Last name

First name

____ / ____ / 2025

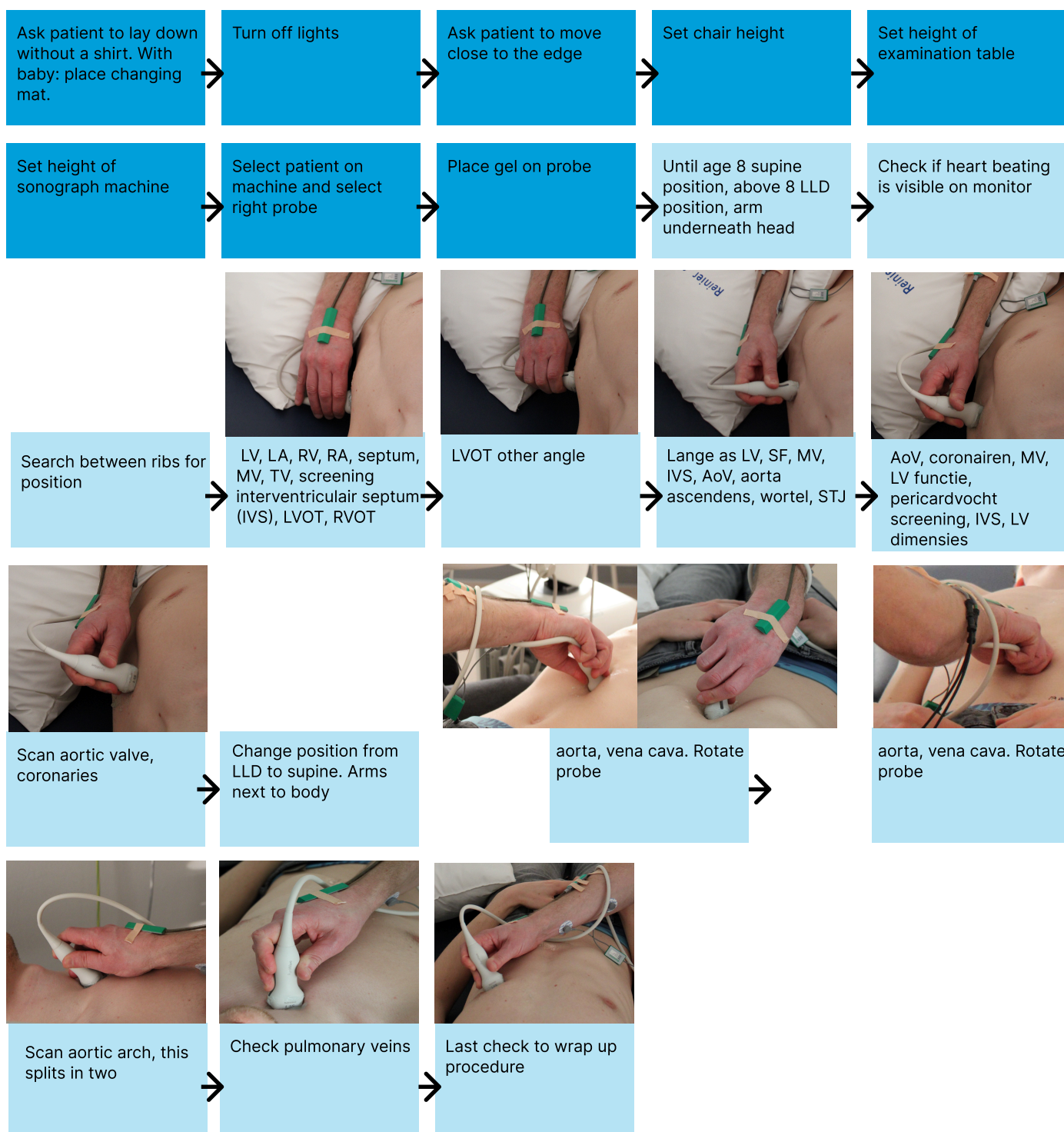
Date (dd/mm/yyyy)

Signature

Appendix B: Procedure TTE

Procedure

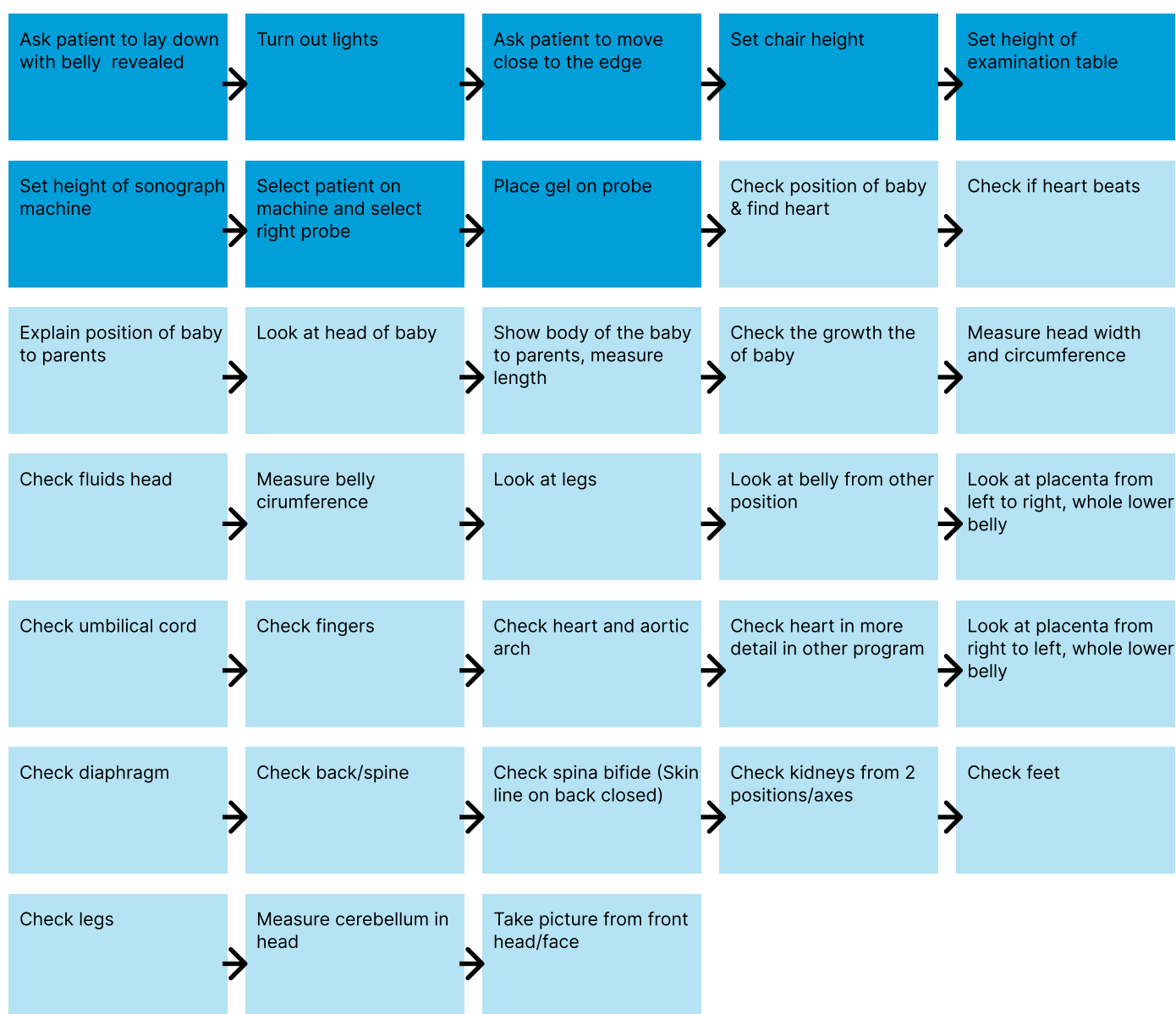
The procedure may differ between younger patients up to 8 years of age and those between 8 and 18 years of age. This line is not fixed but depends on the stature and abilities of the child.



Appendix C: Procedure Gynecology

Procedure

To illustrate the possible procedure for the sonographer, a flowchart has been made of the steps of one of the sonographs observed. It should be noted that each child has a different position, so the steps may vary. Figure below shows the procedure with dark blue as the preparation, which is very similar to paediatric cardiology, and light blue as the steps of the procedure.



Appendix D: RULA results

Rula LLD

RULA Employee Assessment Worksheet

Task Name: _____ Date: _____

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held >1 minute):
Or if action repeated occurs 4X per minute: +1

Step 7: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Table A: Wrist Score

Upper Arm	Lower Arm	Wrist Score			
		1	2	3	4
1	1	1	2	1	2
1	2	2	2	2	3
1	3	2	3	3	3
1	4	2	3	3	3
2	1	2	3	3	3
2	2	3	3	3	3
2	3	3	4	4	4
2	4	3	4	4	4
3	1	3	4	4	4
3	2	3	4	4	4
3	3	4	4	4	4
3	4	4	4	4	4
4	1	4	4	4	4
4	2	4	4	4	4
4	3	4	4	4	4
4	4	4	4	4	4
5	1	5	5	5	5
5	2	5	6	6	6
5	3	6	6	6	6
5	4	6	6	6	6
6	1	7	7	7	7
6	2	8	8	8	8
6	3	9	9	9	9
6	4	9	9	9	9

Table C: Neck, Trunk, Leg Score

Wrist / Arm Score	Neck, Trunk, Leg Score					
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	1	2	3	4	5	6
3	1	2	3	4	5	6
4	1	2	3	4	5	6
5	1	2	3	4	5	6
6	1	2	3	4	5	6
7	1	2	3	4	5	6
8	1	2	3	4	5	6

Scoring (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Table B: Trunk Posture Score

Neck Posture Score	Trunk Posture Score					
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	1	2	3	4	5	6
3	1	2	3	4	5	6
4	1	2	3	4	5	6
5	1	2	3	4	5	6
6	1	2	3	4	5	6

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held >1 minute):
Or if action repeated occurs 4X per minute: +1

Step 14: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

RULA Score

based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

Figure 2.1i: RULA scheme for paediatric ultrasound in LLD position. Scores are noted or encircled.

Rula supine

RULA Employee Assessment Worksheet

Task Name: _____ Date: _____

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



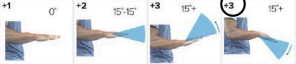
Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held >1 minute):
Or if action repeated occurs 4X per minute: +1

Step 7: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Table A: Wrist Score

Upper Arm	Lower Arm	Wrist Score			
		1	2	3	4
1	1	1	2	1	2
1	2	2	2	2	3
1	3	2	3	3	3
1	4	2	3	3	3
2	1	2	3	3	3
2	2	3	3	3	3
2	3	3	4	4	4
2	4	3	4	4	4
3	1	3	4	4	4
3	2	3	4	4	4
3	3	4	4	4	4
3	4	4	4	4	4
4	1	4	4	4	4
4	2	4	4	4	4
4	3	4	4	4	4
4	4	4	4	4	4
5	1	5	5	5	5
5	2	5	6	6	6
5	3	6	6	6	6
5	4	6	6	6	6
6	1	7	7	7	7
6	2	8	8	8	8
6	3	9	9	9	9
6	4	9	9	9	9

Table C: Neck, Trunk, Leg Score

Wrist / Arm Score	Neck, Trunk, Leg Score					
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	1	2	3	4	5	6
3	1	2	3	4	5	6
4	1	2	3	4	5	6
5	1	2	3	4	5	6
6	1	2	3	4	5	6
7	1	2	3	4	5	6
8	1	2	3	4	5	6

Scoring (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Table B: Trunk Posture Score

Neck Posture Score	Trunk Posture Score					
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	1	2	3	4	5	6
3	1	2	3	4	5	6
4	1	2	3	4	5	6
5	1	2	3	4	5	6
6	1	2	3	4	5	6

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held >1 minute):
Or if action repeated occurs 4X per minute: +1

Step 14: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

RULA Score

based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

Figure 2.1j: RULA scheme for paediatric ultrasound in supine position. Scores are noted or encircled.

RULA top posture

RULA Employee Assessment Worksheet

Task Name: _____

Date: _____

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Lower Arm Score

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:

If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:

Using values from steps 1-4 above, locate score in Table A

Posture Score A

Step 6: Add Muscle Use Score

If posture mainly static (i.e. held >1 minute): +0
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 7: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 8: Find Row in Table C

Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

		Wrist Score			
Table A		1	2	3	4
Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	2
1	2	2	2	2	3
1	3	2	3	3	3
1	4	2	3	3	3
2	1	2	3	3	3
2	2	3	3	3	4
2	3	3	3	3	4
2	4	3	4	4	4
3	1	3	4	4	4
3	2	4	4	4	4
3	3	4	4	4	4
3	4	4	4	4	4
4	1	4	4	4	4
4	2	4	4	4	4
4	3	4	4	4	4
4	4	4	4	4	4
5	1	5	5	5	5
5	2	5	5	5	5
5	3	5	5	5	5
5	4	5	5	5	5
6	1	6	6	6	6
6	2	6	6	6	6
6	3	6	6	6	6
6	4	6	6	6	6

		Neck, Trunk, Leg Score					
Table C		1	2	3	4	5	6
Wrist / Arm Score	Neck, Trunk, Leg Score	1	2	3	4	5	6
1	1	1	2	3	3	4	5
1	2	2	2	3	4	4	5
1	3	3	3	4	4	5	6
1	4	3	3	4	4	5	6
2	1	4	4	4	5	6	7
2	2	4	4	5	6	7	7
2	3	5	5	6	7	7	7
2	4	5	5	6	7	7	7
3	1	5	5	6	7	7	7
3	2	6	6	6	7	7	7
3	3	6	6	6	7	7	7
3	4	7	7	7	7	7	7
4	1	7	7	7	7	7	7
4	2	8	8	8	8	8	8
4	3	8	8	8	8	8	8
4	4	9	9	9	9	9	9

Scoring (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:

If legs and feet are supported: +1
If not: +2

Leg Score

		Neck, Trunk, Leg Score					
Table B: Trunk Posture Score		1	2	3	4	5	6
Neck Posture Score	Legs	Legs	Legs	Legs	Legs	Legs	Legs
1	1	1	2	2	2	2	2
1	2	2	3	3	3	3	3
1	3	3	3	4	4	4	4
1	4	4	4	4	4	4	4
2	1	2	3	3	4	4	4
2	2	3	3	4	4	4	4
2	3	3	4	4	4	4	4
2	4	4	4	4	4	4	4
3	1	3	3	4	4	4	4
3	2	3	3	4	4	4	4
3	3	4	4	4	4	4	4
3	4	4	4	4	4	4	4
4	1	4	4	4	4	4	4
4	2	4	4	4	4	4	4
4	3	5	5	5	5	5	5
4	4	5	5	5	5	5	5
5	1	5	5	5	5	5	5
5	2	6	6	6	6	6	6
5	3	6	6	6	6	6	6
5	4	7	7	7	7	7	7
6	1	7	7	7	7	7	7
6	2	8	8	8	8	8	8
6	3	8	8	8	8	8	8
6	4	9	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:

Using values from steps 9-11 above, locate score in Table B

Posture B Score

Step 13: Add Muscle Use Score

If posture mainly static (i.e. held >1 minute): +0
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 14: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 15: Find Column in Table C

Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk, Leg Score

based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

Rula distal side

RULA Employee Assessment Worksheet

Task Name: _____

Date: _____

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Lower Arm Score

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:

If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:

Using values from steps 1-4 above, locate score in Table A

Posture Score A

Step 6: Add Muscle Use Score

If posture mainly static (i.e. held >1 minute): +0
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 7: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 8: Find Row in Table C

Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

		Wrist Score			
Table A		1	2	3	4
Upper Arm	Lower Arm	Wrist Twist	Wrist Twist	Wrist Twist	Wrist Twist
1	1	1	2	2	2
1	2	2	2	2	3
1	3	2	3	3	3
1	4	2	3	3	3
2	1	2	3	3	3
2	2	3	3	3	4
2	3	3	3	3	4
2	4	3	4	4	4
3	1	3	4	4	4
3	2	4	4	4	4
3	3	4	4	4	4
3	4	4	4	4	4
4	1	4	4	4	4
4	2	4	4	4	4
4	3	4	4	4	4
4	4	4	4	4	4
5	1	5	5	5	5
5	2	5	5	5	5
5	3	5	5	5	5
5	4	5	5	5	5
6	1	6	6	6	6
6	2	6	6	6	6
6	3	6	6	6	6
6	4	7	7	7	7
7	1	7	7	7	7
7	2	8	8	8	8
7	3	8	8	8	8
7	4	9	9	9	9

		Neck, Trunk, Leg Score					
Table C		1	2	3	4	5	6
Wrist / Arm Score	Neck, Trunk, Leg Score	1	2	3	4	5	6
1	1	1	2	3	3	4	5
1	2	2	2	3	4	4	5
1	3	3	3	4	4	5	6
1	4	3	3	4	4	5	6
2	1	4	4	4	4	5	6
2	2	4	4	4	4	5	6
2	3	5	5	5	5	6	7
2	4	5	5	5	5	6	7
3	1	5	5	5	5	6	7
3	2	6	6	6	6	7	7
3	3	6	6	6	6	7	7
3	4	7	7	7	7	7	7
4	1	7	7	7	7	7	7
4	2	8	8	8	8	8	8
4	3	8	8	8	8	8	8
4	4	9	9	9	9	9	9

Scoring (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1

Rula proximal side

RULA Employee Assessment Worksheet

Task Name:

Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

2
Upper Arm Score

Step 2: Locate Lower Arm Position:



Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

2
Lower Arm Score

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

1
Wrist Twist Score

Step 4: Wrist Twist:

If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

3
Wrist Score

Step 5: Look-up Posture Score in Table A:

Using values from steps 1-4 above, locate score in Table A

4
Posture Score A

Step 6: Add Muscle Use Score

If posture mainly static (i.e. held > 1 minute),
Or if action repeated occurs 4X per minute: +1

0
Muscle Use Score

Step 7: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

2
Force / Load Score

Step 8: Find Row in Table C

Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in Table C.

6
Wrist & Arm Score

Scores

Table A		Wrist Score			
Upper Arm	Lower Arm	Wrist			
		Twist	Twist	Twist	Twist
1	1	1	2	2	3
1	2	2	2	2	3
1	3	2	3	3	3
1	4	2	3	3	3
2	1	2	3	3	3
2	2	3	3	3	3
2	3	3	3	3	3
2	4	3	3	3	3
3	1	3	3	3	3
3	2	3	3	3	3
3	3	3	3	3	3
3	4	3	3	3	3
4	1	3	3	3	3
4	2	3	3	3	3
4	3	3	3	3	3
4	4	3	3	3	3
5	1	5	5	5	5
5	2	5	5	5	5
5	3	5	5	5	5
5	4	5	5	5	5
6	1	7	7	7	7
6	2	7	7	7	7
6	3	7	7	7	7
6	4	7	7	7	7

Table C		Neck, Trunk, Leg Score						
Wrist / Arm Score		1	2	3	4	5	6	7+
		1	1	2	3	3	4	5
2	2	2	2	3	4	4	5	5
3	3	3	3	3	4	4	5	6
4	4	3	3	3	4	4	5	6
5	5	4	4	4	5	5	6	7
6	6	4	4	5	5	6	7	7
7	7	5	5	6	6	7	7	7
8+	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

6
RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

2
Neck Score

Step 10: Locate Trunk Position:



Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

3
Trunk Score

Step 11: Legs:

If legs and feet are supported: +1
If not: +2

1
Leg Score

Table B: Trunk Posture Score		Neck Posture Score					
Neck Posture Score		1	2	3	4	5	6
		1	1	2	2	3	3
2	2	2	2	3	3	4	4
3	3	3	3	4	4	5	5
4	4	4	4	5	5	6	6
5	5	5	5	6	6	7	7
6	6	6	6	7	7	8	8

Step 12: Look-up Posture Score in Table B:

Using values from steps 9-11 above,
locate score in Table B

4
Posture B Score

Step 13: Add Muscle Use Score

If posture mainly static (i.e. held > 1 minute),
Or if action repeated occurs 4X per minute: +1

0
Muscle Use Score

Step 14: Add Force/Load Score

If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

1
Force / Load Score

Step 15: Find Column in Table C

Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in Table C.

5
Neck, Trunk, Leg Score

Appendix E: EMG test plan

SEMG test Reinier 17/02

Surface EMG test during an ultrasound

Prepared by: Sanne ten Hoopen

1. Introduction

The goal of this test is to collect electric signals from the muscle during sonography and the corresponding angles with each posture. The test will be in Reinier de Graaf Hospital in the working environment of the doctor.

2. Testing Resources

Tester's name and role

- R1 Sanne: Leads testing, starts measurements, and makes pictures during the test.
- Sonographer/ Dr: Perform sonography. Try to recreate the normal ultrasound routine.
- Simulated patient (SP): Lay on a hospital stretcher and follow instructions from the sonographer.

3. Scope of Testing

- In scope: EMG during rest and EMG while performing sonography on the SP of the heart.
- Out of scope: Working behind the computer.

4. Testing approaches

Method:

This study will employ a **surface EMG (sEMG) analysis** to monitor muscle activation levels in the key shoulder and lower arm muscles of the sonographer while performing ultrasound scans. The test will focus on evaluating muscle effort during different scanning positions and different ways of holding the probe. Next to this, a goniometer will be used to register the different angles of the shoulder and wrist.

The following supplies are needed for this test (also see Figure 1):

1. 4x cable to connect the goniometer
2. Charger laptop
3. Instructions
4. Laptop with Biometric software
5. USB stick to save data on
6. Double-sided tape to attach the goniometer on the skin
7. One-sided tape to attach the goniometer on the skin
8. Alcohol to clean skin

9. Cotton cloth for alcohol
10. Button to mark time stamps
11. EMG wires
12. Datalog + belt
13. 2x spare batteries
14. Bluetooth stick to connect Datalog with computer
15. 6x EMG sensor
16. Goniometer to check angles
17. 2x Goniometer SG110
18. Ground strap
19. 2x Camera
20. 2x tripod
21. Note-taking booklet + pen
22. Discomfort map

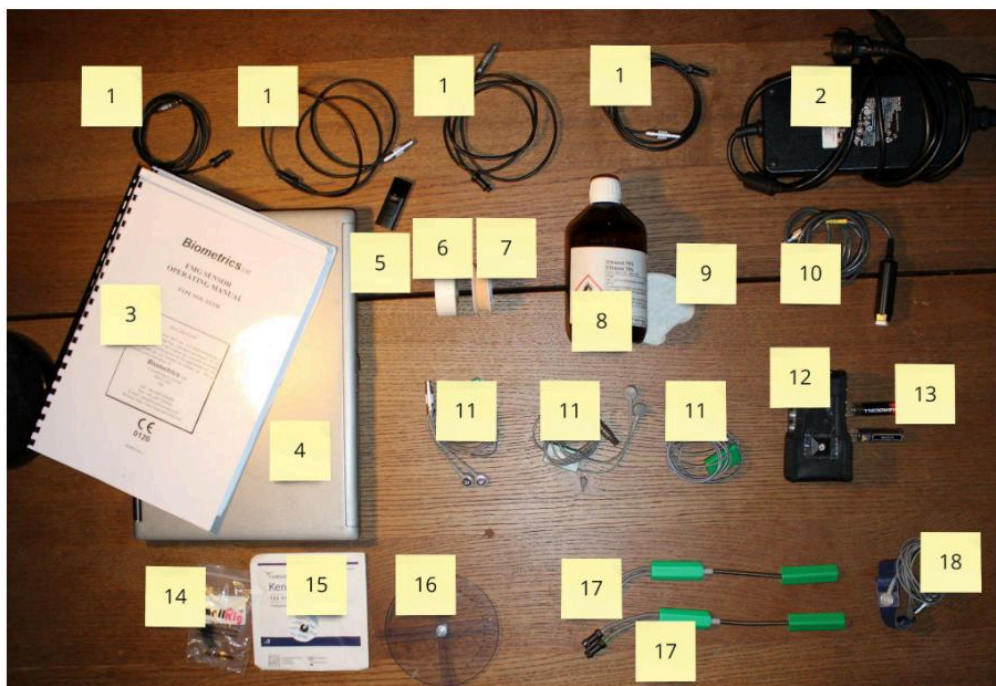


Figure 1: supplies needed

The following muscles will be analyzed:

- Upper trapezium
- Supraspinatus
- Flexo digitorum profundus

The following joints will be analyzed:

- Shoulder
 - Green plug: Flexion/Extension
 - Grey plug: Retraction/Protraction
- Wrist
 - Green plug: Radial/ulnar deviation
 - Grey plug: Flexion/extension

The placement of the EMG is based on other EMG research. The placement is shown in Figure 2.

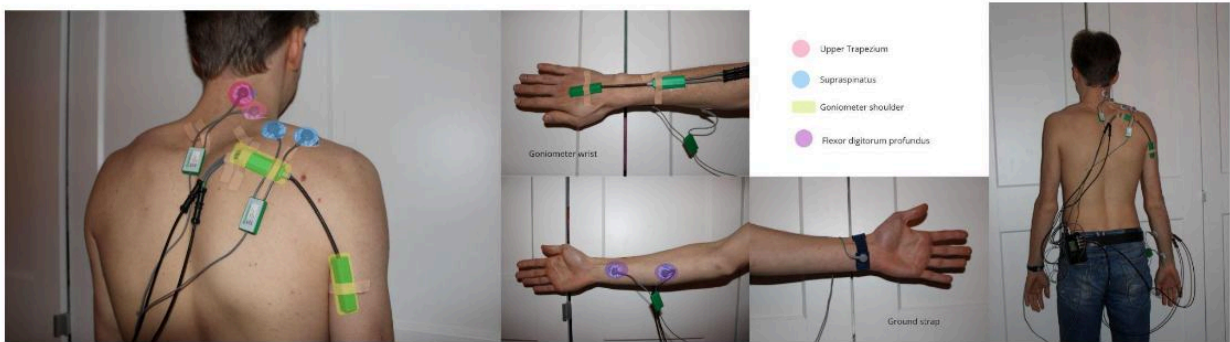


Figure 2: Placement of electrodes and Goniometer

The setup of the experiment is shown in Figure 3.

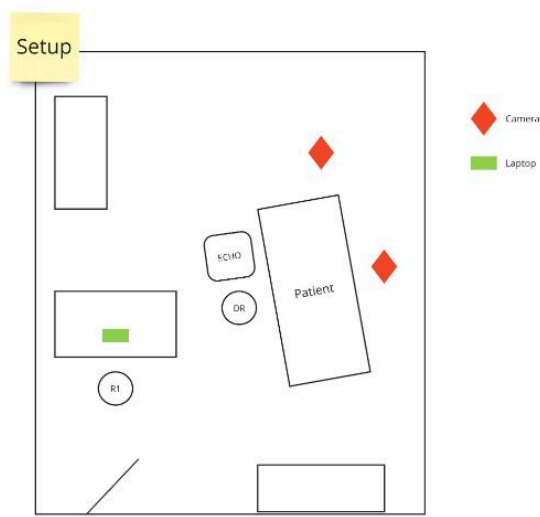


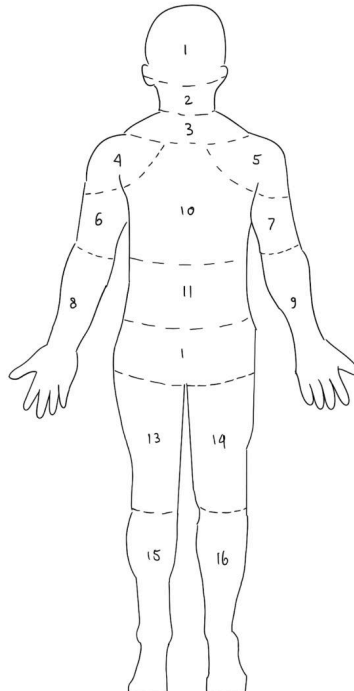
Figure 3: Setup

5. Test Schedule

Timeline

- 15:15 Arrive at hospital
- 15:30 Preparation work
 - Change batteries Datalog
 - Set Up sensor setup in the software
 - Prepare a document to paste graphs in
 - Check SD card is empty & battery is full
- 15:45 Enter Room and setup
 - Informed consent
 - Ask starting questions:
 - Did you perform sonography this morning? How is your discomfort level now? Will you expect to have discomfort today or does it not happen every sonography?
 - Unfold the Tripod, install the cameras
 - Clean skin
 - Place goniometers
 - Place EMG sensors
 - Zero EMG sensors before plugging in
 - Secure everything extra with tape
 - Make before picture
- 16:00 **Test 1:** 0 test (Goals is to have corresponding angles of the goniometer with angles in real life)
- Needed for this test: Goniometers plugged in, 1 camera at the front, goniometer to check angles, button.
 - Explain the test to Dr. Agree to perform Test 3 in the normal way so without the pressure of time.
 - Zero goniometers
 - Start camera and measurement
 - Click the button clearly so the camera can see it
 - Make Dr move the arm up and down to see the angles
 - Document with picture
 - Make Dr move the wrist up and down to see the angles
 - Document with picture
 - Make Dr move wrist side to side to see angles
 - Document with picture
- 16:15 **Test 2:** measure EMG in rest (Goal is to compare rest EMG with echo EMG)
 - Measure EMG data for 2 min while dr sits in a natural posture.
- 16:20 **Test 3:** Measuring while performing echo (Goal is to get angles and muscle activity while performing EMG)
- Needed for this test: pt lies on the hospital stretcher, echo equipment, all sensors plugged in DataLog, button
 - Discuss the different postures that have been analyzed.
 - Note the height of the bed
 - Dr performs the echo and stops the measurement when moves on to the next posture

- Talk out loud when feel discomfort and where in the body and rate it on a scale of 1-10.
 - R1 will have a printed discomfort map and mark places of discomfort. With the audio of the video, the time will be added.
- 16:40 Wrap up
 - Check data & save
 - Save as AC2 with filter and engineering units
 - Make sure to save without the filter *rectify* on
 - Unplug everything from datalog
 - Get sensors of Dr
 - Clean sensors
- 16:45 Dr needs to go



SEMG test Reinier 03/03

Surface EMG test during an ultrasound

Prepared by: Sanne ten Hoopen

1. Introduction

The goal of this test is to collect electric signals from the muscle during sonography and the corresponding angles with each posture. The test will be in Reinier de Graaf Hospital in the working environment of the doctor.

2. Testing Resources

Tester's name and role

- R1 Sanne: Leads testing, starts measurements, and makes pictures during the test.
- Sonographer/ Dr: Perform sonography. Try to recreate the normal ultrasound routine.
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This study will employ a **surface EMG (sEMG) analysis** to monitor muscle activation levels in the key shoulder and lower arm muscles of the sonographer while performing ultrasound scans. The test will focus on evaluating muscle effort during different scanning positions and different ways of holding the probe. Next to this, a goniometer will be used to register the different angles of the shoulder and wrist.

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5. USB stick to save data on
6. Double-sided tape to attach the goniometer on the skin
7. One-sided tape to attach the goniometer on the skin
8. Alcohol to clean skin

9. Cotton cloth for alcohol
10. Button to mark time stamps
11. EMG wires
12. Datalog + belt
13. 2x spare batteries
14. Bluetooth stick to connect Datalog with computer
15. 6x EMG sensor
16. Goniometer to check angles
17. 2x Goniometer SG110
18. Ground strap
19. 2x Camera
20. 2x tripod
21. Note-taking booklet + pen
22. Discomfort map
23. Tape measurer

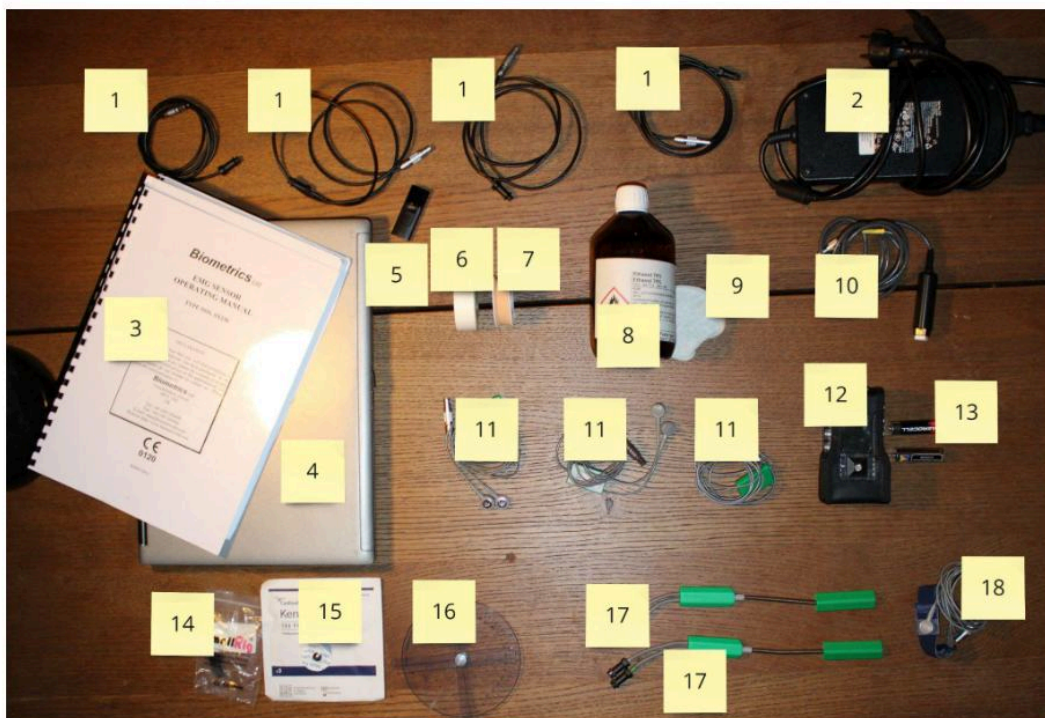


Figure 1: supplies needed

The following muscles will be analysed:

- Upper trapezium
- Supraspinatus
- Flexo digitorum profundus

The following joints will be analyzed:

- Shoulder
 - Green plug: Flexion/Extension
 - Grey plug: Retraction/Protraction
- Wrist
 - Green plug: Radial/ulnar deviation
 - Grey plug: Flexion/extension

The placement of the EMG is based on other EMG research. The placement is shown in Figure 2.

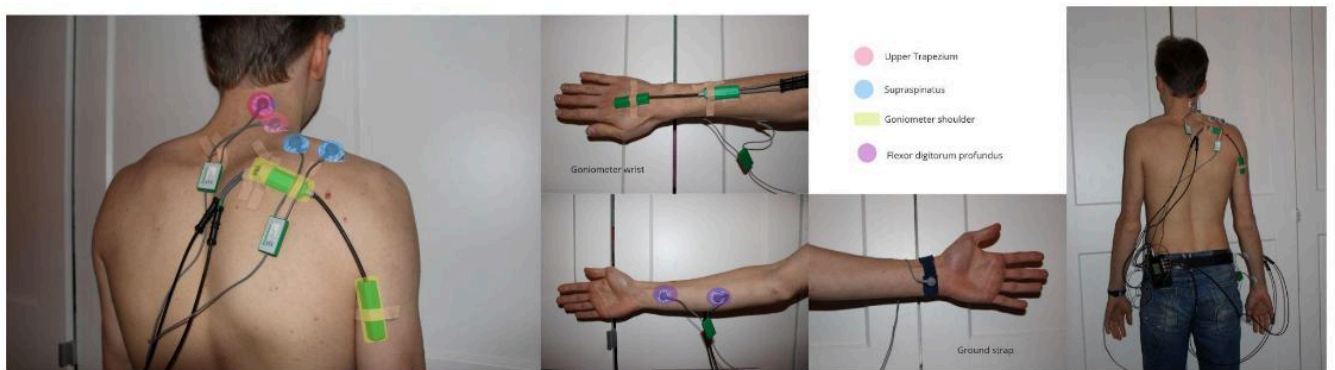


Figure 2: Placement of electrodes and Goniometer

The setup of the experiment is shown in Figure 3.

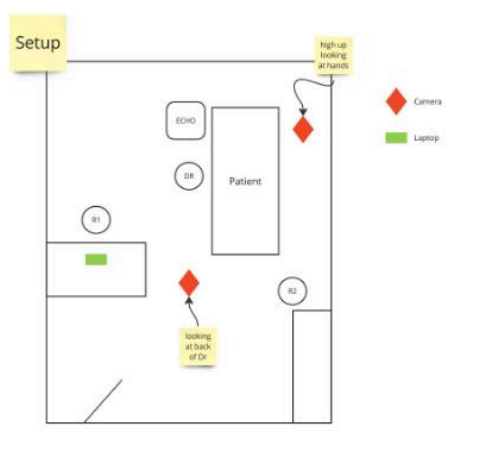


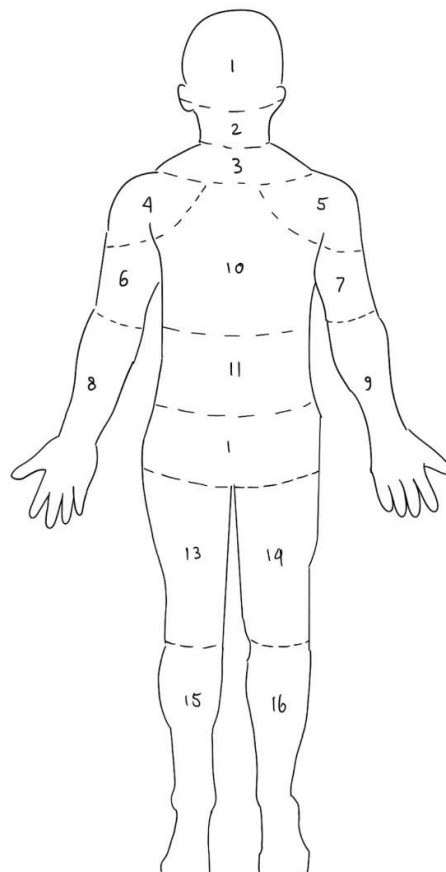
Figure 3: Setup

5. Test Schedule

Timeline

- 14:00 Preparation work
 - Change batteries Datalog
 - Check gonio works
 - Set Up sensor setup in the software
 - Check SD card is empty & battery is full
- 15:30 Pick up cameras at uni
- 16:00 Pick up researcher 2 at station
- 16:15 Arrive at hospital
- 16:30 Enter Room and setup
 - Informed consent
 - Ask starting questions:
 - Did you perform sonography this morning? How is your discomfort level now? Will you expect to have discomfort today or does it not happen every sonography?
 - Unfold the Tripod, install the cameras
 - Clean skin
 - Place goniometers
 - Place EMG sensors
 - Zero EMG sensors before plugging in
 - Secure everything extra with tape
 - Make a before picture
- 16:45 **Test 1:** 0 test (Goal is to have corresponding angles of the goniometer with angles in real life)
- Needed for this test: Goniometers plugged in, 1 camera at the front, goniometer to check angles, button.
 - Explain the test to Dr. Agree to perform Test 3 in the normal way so without the pressure of time.
 - Zero goniometers
 - Start camera and measurement
 - Click the button clearly so the camera can see it
 - Make Dr move the arm up and down to see the angles
 - Document with picture
 - Make Dr move the wrist up and down to see the angles
 - Document with picture
 - Make Dr move wrist side to side to see angles
 - Document with picture
- 16:50 **Test 2:** measure EMG in rest (Goal is to compare rest EMG with echo EMG)
 - Measure EMG data for 2 min while dr sits in a natural posture.
- 17:00 **Test 3:** Measuring while performing echo (Goal is to get angles and muscle activity while performing EMG)
- Needed for this test: pt lies on the hospital stretcher, echo equipment, all sensors plugged in DataLog, button
 - Discuss the different postures that have been analyzed.
 - Note the height of the bed

- Dr performs the echo and stops the measurement when moves on to the next posture
- Talk out loud when feel discomfort and where in the body and rate it on a scale of 1-10.
 - R1 will have a printed discomfort map and mark places of discomfort. With the audio of the video, the time will be added.
- 17.45 Wrap up
 - Check data & save
 - Save as AC2 with filter and engineering units
 - Make sure to save without the filter *rectify* on
 - Unplug everything from datalog
 - Get sensors of Dr
 - Clean sensors
- 17.45 Dr needs to go



Appendix F: Matlab script

For analysing EMG data:

```
clear all;
close all;
clc;
%% Import Data
scan = '';
scan = "gync";
%scan = "paed";
round=2;
if (scan == "gync")
    pathAdd = "test 3-3";
    if round==2
        pathAdd = "test 28";
    end
elseif (scan == "paed")
    pathAdd = "test 17-2";
    if round==2
        pathAdd = "test 26";
    end
else
    fprintf('Selecteer aub een scan');
    pause
end
WorkPath=append("xxx");
addpath(WorkPath)
%%
aa=importdata('gehele echo.txt');
samplesR = num2str(cell2mat(aa.textdata(end-1)));
samplesD = str2double(extract(samplesR,digitsPattern));
seconds = samplesD(2)/samplesD(3);
totalPoints= size(aa.data);
if scan=="paed" && round==1
    aa.data(:,7) = [];
    aa.textdata(8) = [];
end
if round==2 %filling out/changing columns
    aa.data(:,8)=aa.data(:,5);
    aa.data(:,7)=zeros(totalPoints(1),1);
    aa.data(:,6)=zeros(totalPoints(1),1);
    aa.data(:,5)=aa.data(:,4);
    aa.data(:,4)=aa.data(:,3);
    aa.data(:,3)=zeros(totalPoints(1),1);
end
%%
time = linspace(0,seconds,totalPoints(1));
%namelist = aa.Properties.VariableNames;
namelist = [];
for ii=2:(size(aa.textdata)-1)
    locs = strfind(num2str(cell2mat(aa.textdata(ii))), "");
    namelist = [ namelist; append(extractBetween(aa.textdata(ii),locs(1)+1,locs(2)-1))];
end
namelist = [namelist ; "Button"];
if scan == "paed"&& round==1
    knop= (aa.data(:,7)-30)*100;
else
    knop= (aa.data(:,8)-30)*100;
end
```

```

GoodNames=["Trapezius", "Supraspinatus", "Flexor", "Flex/Extension Shoulder", "Ad/Abduction", "Flex/Extension", "Radial/
Ulnar"];
%% Muscles
figure
plot(time,aa.data(:,1));
hold on
plot(time,aa.data(:,2));
plot(time,aa.data(:,3));
plot(time,knop*0.01);
title('Muscles')
legend(namelist(1:3))
xlabel('Time (s)')
ylabel('Voltage (mV)')
%% Angles
figure
plot(time,aa.data(:,4));
hold on
plot(time,aa.data(:,5));
plot(time,aa.data(:,6));
if scan ~= "paed"
    plot(time,aa.data(:,7));
end
plot(time,knop*0.4);
title('Joint angles')
if scan == "paed"
    legend(namelist(4:7))
else
    legend(namelist(4:8))
end
xlabel('Time (s)')
ylabel('Angle (degrees)')
%% Hoeken2
hold off;
plot(time,aa(:,4));
hold on
plot(time,aa(:,5));
plot(time,aa(:,6));
plot(time,knop*0.5);
title('Joint angles')
legend(namelist{4},namelist{5},namelist{6},'Button')
xlabel('Time (s)')
ylabel('Angle (degrees)')
%% Spieren
hold off;
p1 = plot(time, aa(:,1), 'LineWidth', 1.5, 'Color', [0 0 1 0.6]); % Blue with transparency
hold on;
p2 = plot(time, aa(:,2), 'LineWidth', 1.5, 'Color', [1 0 0 0.6]); % Red with transparency
p3 = plot(time, aa(:,3), 'LineWidth', 1.5, 'Color', [0 1 0 0.6]); % Green with transparency
title('Muscle Activity')
legend(namelist{1}, namelist{2}, namelist{3}, 'Location', 'best')
xlabel('Time (s)')
ylabel('Voltage (mV)')
grid on;
%% Spieren
figure
%plot(time,aa.data(:,1));
hold on
plot(time,aa.data(:,2));
%plot(time,aa.data(:,3));

```



```

plot(time, knop*0.01);
title('Muscles')
legend(namelist{2}, 'Button')
xlabel('Time (s)')
ylabel('Voltage (mV)')
%% Hoeken
figure
%plot(time, aa.data(:,4));
hold on
plot(time, aa.data(:,5));
%plot(time, aa.data(:,6));
%plot(time, aa.data(:,7));
% if scan ~= "paed"
%   plot(time, aa.data(:,7));
% end
plot(time, knop*0.5);
title('Joint angles')
legend(namelist(4), namelist(5));
xlabel('Time (s)')
ylabel('Angle (degrees)')
%% Hoeken
figure
%plot(time, aa.data(:,4));
hold on
%plot(time, aa.data(:,5));
plot(time, aa.data(:,6));
if scan ~= "paed"
    plot(time, aa.data(:,7));
end
plot(time, knop*0.8);
title('Joint angles')
if scan == "paed"
    legend(namelist(6:7))
else
    legend(namelist(4:8))
end
xlabel('Time (s)')
ylabel('Angle (degrees)')
%% average
avg1 = mean(aa.data(1), 2, "omitmissing");
%% Correct GYN1
aa.data(abs(aa.data(:,1)) > 0.5, 1) = 0;
aa.data(abs(aa.data(:,2)) > 0.9, 2) = 0;
%% Correct PAED2.1
aa.data(1:42566,:) = [];
time = time(1:end-42566);
knop = knop(42567:end);
knop(122123:126000) = 100;
seconds = seconds - 42.56;
%% Correct PAED2.2
knop(208000:210000) = 100;
%% Angle + Muscle
correctionF = 2;
correctionS = -7;

```

```

toPlot= [ %1,      %Trapezius
         2,      %Supraspinatus
         %3,      %Flexor
         %4,      %Flex/Extension Shoulder
         5,      %Ad/Abduction
         %6,      %Flex/Extension
         %7,      %Radial/Ulnar
         ];
figure
yyaxis left
ylabel('Voltage (mV)')
for i = toPlot'
    if i>3
        yyaxis right
        plot(time',correctionF*(aa.data(:,i)+correctionS));
    else
        plot(time',aa.data(:,i));
    end
    hold on
end
yyaxis right
ylabel('Angle (degrees)')
plot(time',knop*0.8);    %Button
xlabel('Time (s)')
%yyaxis left
%ylim([-0.6 0.8]);
xlim([0 seconds])
if length(toPlot)==2
    title(GoodNames(toPlot(2))+ " vs " +GoodNames(toPlot(1))+ " (G)")
    legend(GoodNames(toPlot(1)), GoodNames(toPlot(2)), "Button")
else
    title("Ad/Abduction vs Supraspinatus (G)")
    legend(namelist{toPlot}, "Button")
end
yyaxis left
ylabel('Voltage (mV)')
%title("Flex/Extension vs XX (P)")
%% Analyse 30-degrees
Gonio=5;
ThirtyPlus= sum((aa.data(:,Gonio)+correctionS)<(-30/correctionF))/totalPoints(1)*100;
display(ThirtyPlus);
plot(time',((aa.data(:,Gonio)+correctionS)<(-30/correctionF)))

```

For comparing EMG data test and retest:

```
plot(time',knop*0.01);
ticlear all;
close all;
clc;
%% Import Data
%scan = "gync";
%scan = "paed1";
scan = "paed2";
if (scan == "gync")
    pathAdd1 = "test 3-3";
    WorkPath1=append("xxx");
    addpath(WorkPath1)
    ---
    fprintf('Selecteer aub een scan');
    pause
end
%%
if scan=="gync"
    aa.rest1=importdata('test 3-3/rust.txt');
    aa.test1=importdata('test 3-3/hele echo2.0.txt');
    aa.rest2=importdata('test 28/rust emg.txt');
    aa.test2=importdata('test 28/gehele echo.txt');
elseif scan=="paed1"
    aa.rest1=importdata('test 17-2/rust emg.txt');
    aa.test1=importdata('test 17-2/1e echo.txt');
    aa.rest2=importdata('test 26/stil emg.txt');
    aa.test2=importdata('test 26/1e.txt');
elseif scan=="paed2"
    aa.rest1=importdata('test 17-2/rust emg.txt');
    aa.test1=importdata('test 17-2/2e echo.txt');
    aa.rest2=importdata('test 26/stil emg.txt');
    aa.test2=importdata('test 26/2e.txt');
end
%%
samplesT = str2double(extract(num2str(cell2mat(aa.test2.textdata(end-1))),digitsPattern));
samplesRate= samplesT(4);
totalPointsT = size(aa.test2.data);
samplesR = str2double(extract(num2str(cell2mat(aa.rest2.textdata(end-1))),digitsPattern));
totalPointsR = size(aa.rest2.data);
%filling out/changing columns
aa.test2.data(:,8)=aa.test2.data(:,5);
aa.test2.data(:,7)=zeros(totalPointsT(1),1);
aa.test2.data(:,6)=zeros(totalPointsT(1),1);
aa.test2.data(:,5)=aa.test2.data(:,4);
aa.test2.data(:,4)=aa.test2.data(:,3);
aa.test2.data(:,3)=zeros(totalPointsT(1),1);
aa.rest2.data(:,8)=aa.rest2.data(:,5);
aa.rest2.data(:,7)=zeros(totalPointsR(1),1);
aa.rest2.data(:,6)=zeros(totalPointsR(1),1);
aa.rest2.data(:,5)=aa.rest2.data(:,4);
aa.rest2.data(:,4)=aa.rest2.data(:,3);
aa.rest2.data(:,3)=zeros(totalPointsR(1),1);
```

```

%% TrapeziusNormalised
threshold = 0.5;
rest1avg=GetRMSmean(aa.rest1.data(:,1));
rest2avg=GetRMSmean(aa.rest2.data(:,1));
figure
AnalyseAndPlot(aa.test1.data(:,1),threshold,rest1avg);
hold on
AnalyseAndPlot(aa.test2.data(:,1),threshold,rest2avg);
xlabel('Time (s)')
ylabel('Normalised EMG RMS (-)')
title('Normalised RMS of EMG Signal Trapezius (P)')
legend('Test', 'Retest')
%% SupraspinatusNormalised
threshold = 0.9;
rest1avg=GetRMSmean(aa.rest1.data(:,2));
rest2avg=GetRMSmean(aa.rest2.data(:,2));
figure
AnalyseAndPlot(aa.test1.data(:,2),threshold,rest1avg);
hold on
AnalyseAndPlot(aa.test2.data(:,2),threshold,rest2avg);
xlabel('Time (s)')
ylabel('Normalised EMG RMS (-)')
title('Normalised RMS of EMG Signal Supraspinatus')
legend('Test', 'Retest')
%% Correct GYN2
aa.test2.data(1100000:end,:)=[];
%%
function AnalyseAndPlot(emg,threshold,normFactor)
    if nargin<3
        normFactor=1;
    end
    emg = emg(isfinite(emg));
    fs = 1000; % Sampling frequency (Hz), update to match your data
    [b, a] = butter(4, [20 450]/(fs/2), 'bandpass');
    emg_filtered = filtfilt(b, a, emg);
    emg_rectified = abs(emg_filtered);
    window_size = 0.1 * fs; % 100 ms window
    emg_rms = sqrt(movmean(emg_rectified.^2, window_size));
    emg_rms(emg_rms>threshold) = mean(emg_rms);
    t = (0:length(emg)-1)/fs; % Time vector
    plot(t, emg_rms/normFactor)
end
%%
function Avg = GetRMSmean(emg)
    emg = emg(isfinite(emg));
    fs = 1000; % Sampling frequency (Hz), update to match your data
    [b, a] = butter(4, [20 450]/(fs/2), 'bandpass');
    emg_filtered = filtfilt(b, a, emg);
    emg_rectified = abs(emg_filtered);
    window_size = 0.1 * fs; % 100 ms window
    emg_rms = sqrt(movmean(emg_rectified.^2, window_size));
    Avg = mean(emg_rms);
end
%%
function AnalyseAndPlot2(emg,threshold,normFactor)
    if nargin<3
        normFactor=1;
    end
    emg = emg(isfinite(emg));
    fs = 1000; % Sampling frequency (Hz), update to match your data
    [b, a] = butter(4, [20 450]/(fs/2), 'bandpass');
    emg_filtered = filtfilt(b, a, emg);
    emg_rectified = abs(emg);
    window_size = 0.1 * fs; % 100 ms window
    emg_rms = sqrt(movmean(emg_rectified.^2, window_size));
    emg_rms(emg_rms>threshold) = mean(emg_rms);
    t = (0:length(emg)-1)/fs; % Time vector
    plot(t, emg_rms/normFactor)
end

```

Appendix G: Flexor results

Flexor Paed Supine

In the supine position, the flexor activity is continuous, as can be seen in Figure 2.3q. The first posture has a lot of flexion. It is remarkable that the force that is needed for the first position is not seen in the muscle activity. This could mean that the force comes out of the arm and shoulder muscles, rather than the flexor.

When the arm is abducted and a downward force is applied, the shoulder muscles must counteract the torque created by the extended limb. The deltoid, particularly its middle fibres, plays a crucial role in maintaining arm position and generating the force required for downward pressing. The supraspinatus assists in stabilising the humeral head ensuring efficient force transmission.

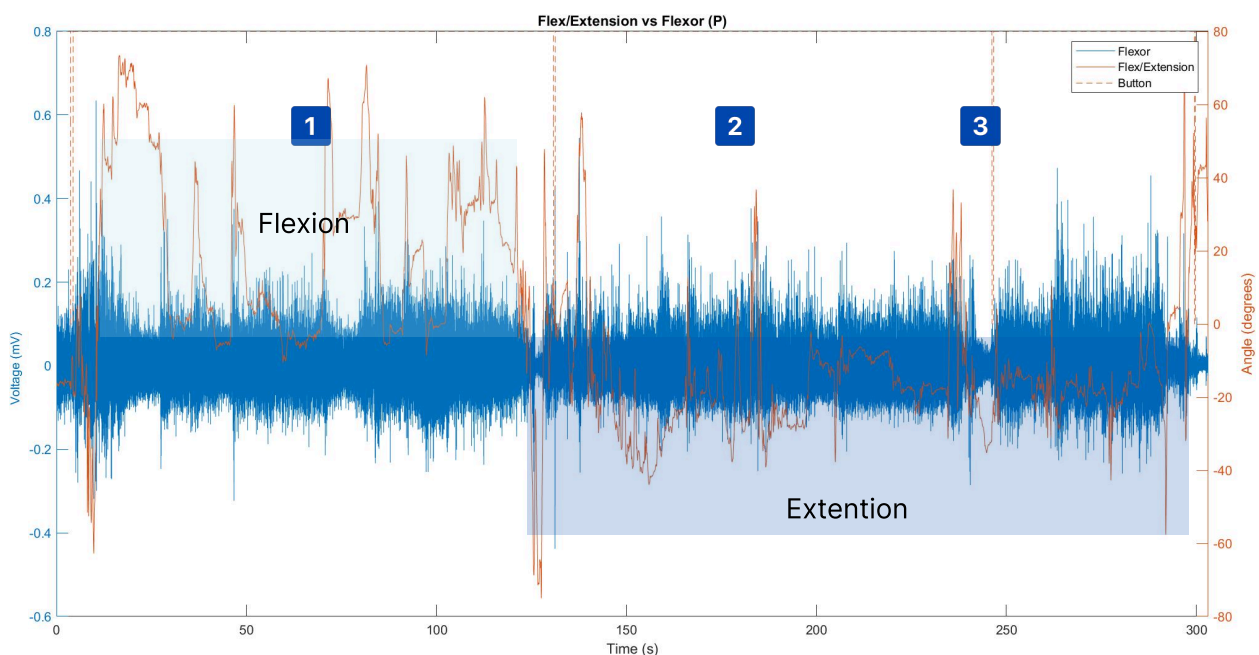


Figure 2.3q: Flexor versus Flex/Extension

Flexor Gyn

In the first posture, the wrist is at a neutral angle and the muscle activity is stable. In the second posture the wrist is flexed with a stable muscle activity. In the third posture the muscle activity is way higher because the arm is next to the torso resulting in force coming from the lower arm. See Figure 2.3aa.1-3.

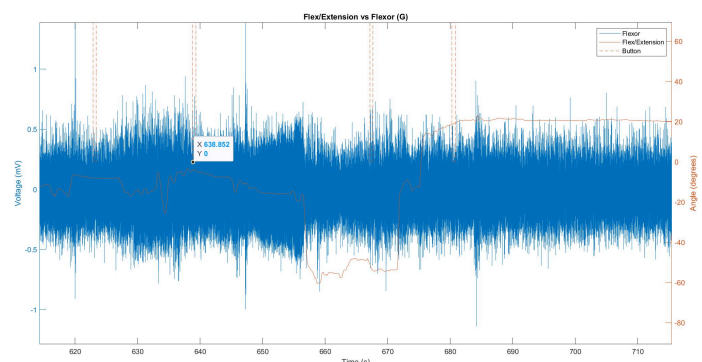


Figure 2.3aa.1: Muscle activity Flexor in posture 2

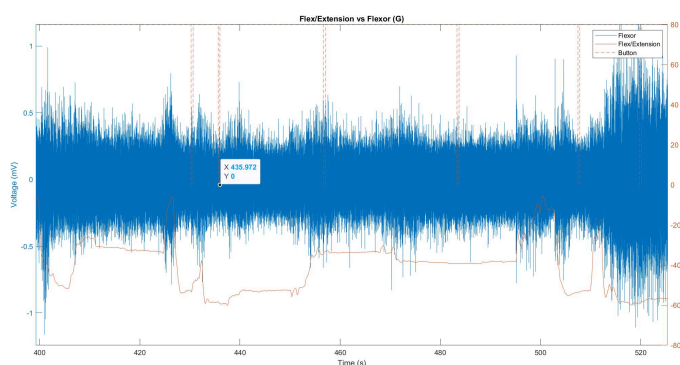


Figure 2.3aa.1: Muscle activity Flexor in posture 1

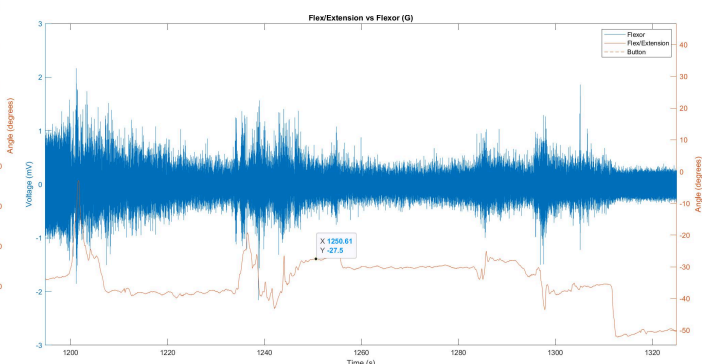


Figure 2.3aa.1: Muscle activity Flexor in posture 3

Appendix H: Buttons pressed

Results T2

This test registered 43 points during the full sonograph:

1. 0 minutes, 3.839 seconds (3.83892 seconds)
2. 0 minutes, 15.727 seconds (15.7267 seconds)
3. 0 minutes, 45.399 seconds (45.3991 seconds)
4. 0 minutes, 58.020 seconds (58.0198 seconds)
5. 1 minute, 3.696 seconds (63.6957 seconds)
6. 1 minute, 18.248 seconds (78.2484 seconds)
7. 2 minutes, 11.697 seconds (131.697 seconds)
8. 2 minutes, 25.177 seconds (145.177 seconds)
9. 2 minutes, 49.647 seconds (169.647 seconds)
10. 3 minutes, 20.852 seconds (200.852 seconds)
11. 3 minutes, 44.686 seconds (224.686 seconds)
12. 3 minutes, 53.795 seconds (233.795 seconds)
13. 4 minutes, 20.145 seconds (260.145 seconds)
14. 5 minutes, 13.244 seconds (313.244 seconds)
15. 5 minutes, 43.243 seconds (343.243 seconds)
16. 5 minutes, 55.743 seconds (355.743 seconds)
17. 6 minutes, 28.750 seconds (388.75 seconds)
18. 7 minutes, 10.421 seconds (430.421 seconds)
19. 7 minutes, 15.641 seconds (435.641 seconds)
20. 7 minutes, 36.640 seconds (456.64 seconds)
21. 8 minutes, 3.340 seconds (483.34 seconds)
22. 8 minutes, 27.490 seconds (507.49 seconds)
23. 8 minutes, 40.147 seconds (520.147 seconds)
24. 9 minutes, 12.346 seconds (552.346 seconds)
25. 9 minutes, 44.782 seconds (584.782 seconds)
26. 10 minutes, 22.887 seconds (622.887 seconds)
27. 10 minutes, 39.262 seconds (639.262 seconds)
28. 11 minutes, 7.186 seconds (667.186 seconds)
29. 11 minutes, 20.286 seconds (680.286 seconds)
30. 12 minutes, 14.835 seconds (734.835 seconds)
31. 12 minutes, 35.810 seconds (755.81 seconds)
32. 13 minutes, 3.349 seconds (783.349 seconds)
33. 13 minutes, 29.983 seconds (809.983 seconds)
34. 15 minutes, 7.123 seconds (907.123 seconds)
35. 15 minutes, 38.531 seconds (938.531 seconds)
36. 16 minutes, 49.390 seconds (1009.39 seconds)
37. 17 minutes, 10.680 seconds (1030.68 seconds)
38. 17 minutes, 51.640 seconds (1071.64 seconds)
39. 18 minutes, 0.720 seconds (1080.72 seconds)
40. 18 minutes, 27.360 seconds (1107.36 seconds)
41. 18 minutes, 58.130 seconds (1138.13 seconds)
42. 23 minutes, 0.620 seconds (1380.62 seconds)
43. 23 minutes, 22.870 seconds (1402.87 seconds)

Stops measuring at 23:34

Results T2

Explanation of what happened at these points

1. Start of measurements
2. Change position
3. Look at growth baby
4. Change position
5. Finding new position because baby was moving
6. Belly baby
7. Far reaching position
8. Turned probe
9. Change position looking at legs
10. Other angle to look at belly baby
11. Find position to look at belly baby
12. Change position
13. Placenta
14. Umbilical cord
15. Umbilical cord
16. Fingers
17. Heart in other program
18. Other position heart
19. Other position heart
20. Other position heart (chamber flow, aortic)
21. Other position heart (aortic arch)
22. Other position heart (blood vessels to head)
23. Other position heart (chambers)
24. Diaphragm
25. Spine
26. Skin line (reaching far)
27. Kidneys
28. Other position kidneys (reaching far). Holding probe differently
29. Other position kidneys cross section
30. Other position kidneys length
31. Looking for face
32. Seeing hands and feet
33. Legs
34. Turns towards patient to have more room elbow
35. Baby face to back of mom. Ask patient to move lower and tilt pelvis.
36. Elbow close to body
37. Seeking position to see the head → moving table higher to tilt pelvis more
38. Seeking position to see the head
39. Moving from close to the body to middle still looking face
40. Close to the body resulting in pulled up shoulder
41. Awkward position close to body
42. Try to see face
43. Middle lower side belly

Results T2

Extra time stamps made will analyzing:

A:

04:29 Mentioned feeling her upper arm 3/10 and shoulderblades on the right side (2/10) when she can't lean on the patient with her lower arm.

B:

16:11 Measuring Cerebellum

C:

16:15 mentioned feeling between shoulder blades on the right side and biceps. Feeling more the shoulder blades than the biceps.

D:

17:21 Making small movements with wrist to search for a good view. Having a kink in the wrist.

E:

17:54 Pushing hard

F:

18:05 Switch to other probe

G:

18:24 Awkward position. Elbow close to body.

H:

20:06 Long in this position

I:

20:50 Mentioned feeling lower arm due to pushing with fingers. Wrist not in neutral position.

J:

21:43 Pushing

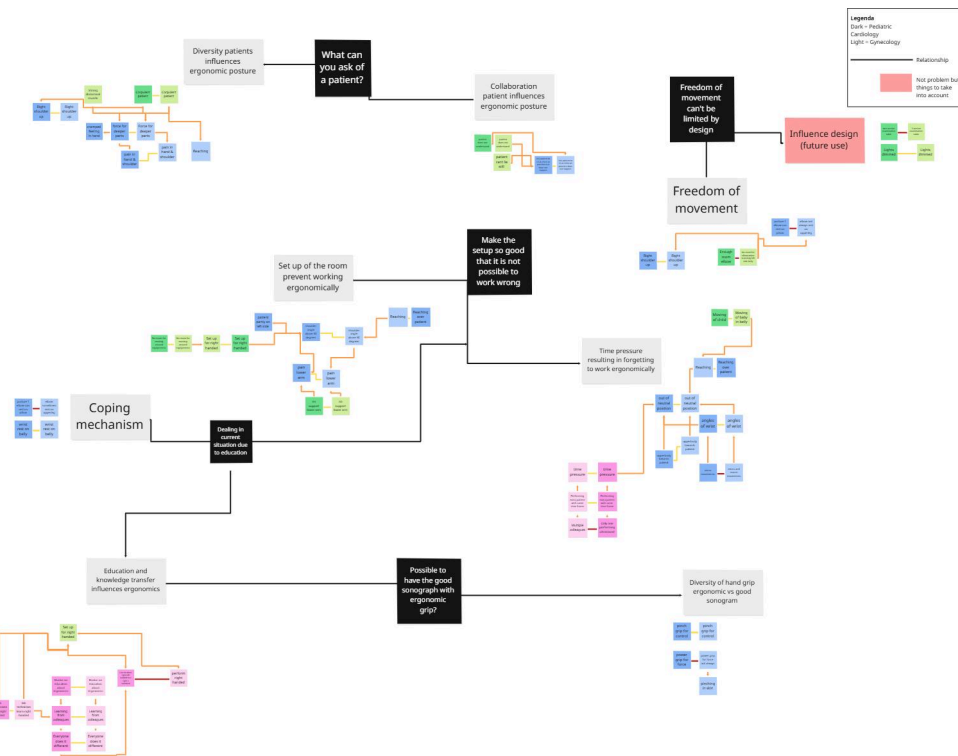
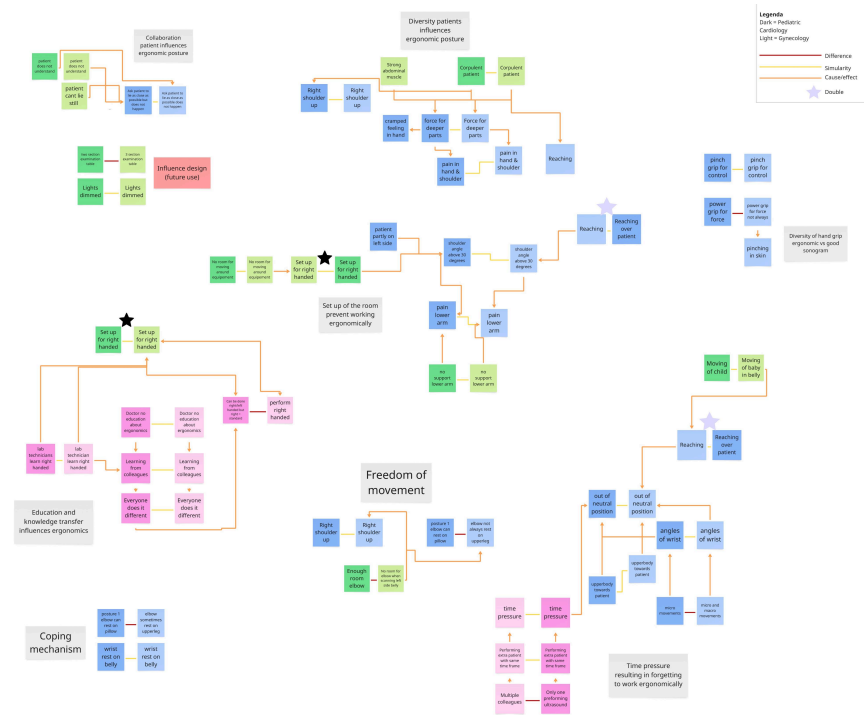
K:

23:06 Left side pushing

L:

23:23 stop measuring said on video

Appendix I: Flexor results



Appendix J: Explanation ideation activities

Brainstorm fellow students

Four fellow students from the three Industrial Design Engineering master's programmes were invited to participate. The group was made of a mix of Medesign and non-Medesign students to create diversity. First, the students were introduced to the context and the problem. Then, they were asked to do a brain dump to get all their questions on the table.

The brainstorming session began with the lotus flower technique. This technique enables students to build on each other's ideas. We then discussed our findings and selected the five most promising and interesting ideas. These were passed on to every student, who then had three minutes to brainstorm each one.

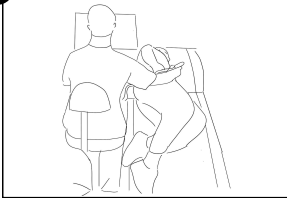
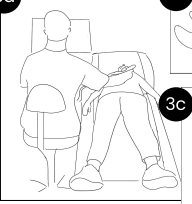
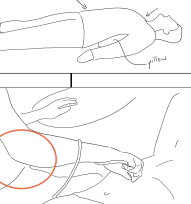
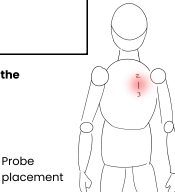
Co-creation hospital

The aim of this co-creation session was to validate my findings, identify any missing information and facilitate discussion between professionals from different backgrounds.

Seven professionals took part in the brainstorm, including a gynaecologist, a paediatrician, health and safety environment coordinators, medical instrumentation technicians and a liaison officer.

First, insights were shared using 'praatplaten' shown on the next page. This gave everyone the opportunity to understand the problem and be on the same page. It also initiated a conversation between the two doctors, who have different routines for performing ultrasounds. The professionals were split into two groups, ensuring that every profession was represented. They discussed problematic and positive aspects, as well as wishes, and wrote them on an A2 sheet of paper.

Paediatric Cardiology Ultrasound of the heart

Phases	1. Product USE Scenario			
	 Patient on left side (LLD position) • Patient is asked to move as close as possible • Doctor sets height of stool and examination bed	 Pillow is place between the arm of the doctor and the patient.	 Patient in supine position • Place pillow underneath back to make subcostal and parasternal view easier (see 3B) • Floating elbow observed (see 3C)	 Patient in supine position
Actions	 Probe placement		 Probe placement	

2. PRODUCT USE Experience

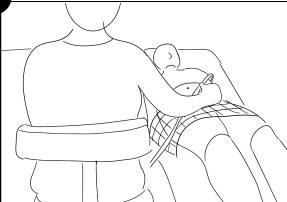
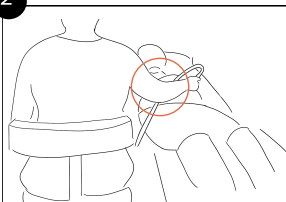
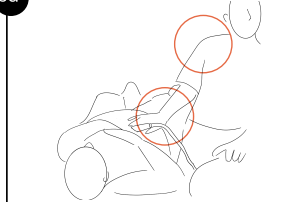
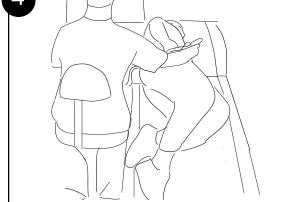
Experiences	 1 Child cries or moves making imaging difficult.	 2 Doctor can still lean on patient while there is less skin-to-skin contact.
	 1 Forcing wrong posture to still perform the ultrasound Reaching to other side patient causes pain in shoulder and arm.	2 Pillow sometimes slips away. Shoulder pain due to abduction of arm.
Pain points		3b Apply a lot of force for imaging subcostal view. 3c Floating elbow

3. Facts

- 🕒 10 min checkup
15-20 min new patient
- 👉 Micro movements
- 👊 Force at cardiology: average 3.96 KG
With Obese patients: 27,6 KG



Gynaecology Ultrasound of baby in uterus

Phases	1. Product USE Scenario			
	 Middle lower part belly • Patient is asked to move as close as possible • Doctor sets height of stool and examination bed	 Right side upper part of belly	 Left side belly • Tilt the probe that thumb is under and the rest of the hand on the probe.	 Patient on his/her side • Turn patient as soon as you notice patient getting lightheaded.
Actions				

2. PRODUCT GEBRUIK ERVARING

Experience	 1 Arm doctor rests on patient's thigh where towel lies	During explanation: keep probe in same position so you know where you left off	 4 Keeping an eye on the patient to make sure things are going well.
	 Forcing incorrect posture when baby moves	2 Floating elbow Reaching to other side patient causes pain in shoulder and arm.	3 Kink in wrist Shoulder pushed up to get into position

3. Facts

- 🕒 45 min
- 👉 Micro and macro movements



Provotyping

Provotyping is a method to quickly provoke a reaction with a simple prototype to eliminate the obvious flaws in the design. It was used just after the midterm to get the iterating on the design directions started.

This qualitative research was done to provoke engagement of the user. The method was used on a health and safety environment (HSE) coordinator and a sonographer from the radiology department to

The research was done using the following steps:

1. Explaining the two concepts: leaning support and hanging support.
2. Trying out concepts
3. Guiding questions:
 - a. What are the most important things to look out for?
 - b. What part of the product should be different?

Brainstorm fellow student 2

The goal of this brainstorm was to discover opportunities in the domain of the newly formulated design goal and to iterate on the leaning supports presented during the midterm presentation.

The brainstorm was conducted with three fellow IPD students with a mix of interest in the medical field. IPD students were chosen to focus mostly on product solutions. This session encompassed five key components:

- 1. Context introduction and problem introduction:** Participants were informed about the context of the problem in the hospital. The introduction was aimed to create a better understanding of the problem due to the lack of medical knowledge of the participants.
- 2. How-Tos:** Four How-Tos were presented about the following topics that are interesting for a support tool: folding/storage, universality (fitting every body shape), flexibility and support of elbow/shoulder. Every participant worked on a question for three minutes and then passed the paper to the next participant.
- 3. Discussion How-Tos:** The goal of the discussion was to find promising ideas and combine those to create design directions.
- 4. Idea explanation:** the leaning support was presented with sketches and the prototype. Participant were allowed to try it out themselves to understand the workings (see Figure 4.5i).
- 5. SCAMPER:** The method SCAMPER (consisting of the categories: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse) was used to find variations of Midterm idea x to explore possible other directions. As a group we brainstormed about each category for three minutes building onto each other's ideas.

Appendix K: Expert testing plan

Benodigdheden

- Beide prototypes (schoon en klaar voor gebruik)
- Informed consent formulieren
- Demografische vragenlijst & evaluatie document excel
- Comfort score formulier (2 per participant)
- Pen/papier of tablet/laptop voor notities
- Stopwatch of timer
- Desinfectiemiddel / schoonmaakmateriaal (tussen testen)
- Fotocamera

Structuur testsessie

1. Introductie (2 minuten)

- Voorstellen en uitleggen van het doel
 - Doel: verminderen van werk gerelateerde musculoskeletale klachten veroorzaakt door echografie.
 - Doel test: Testen van twee support systemen om te kijken welke meest comfortabel is het past bij de werkwijze.
- Toelichting op testprocedure
- Vragen om toestemming (mondeling en schriftelijk)
- Garanderen van anonimiteit en vrijwilligheid

2. Demografische gegevens verzamelen (2 minuten)

Vragenlijst invullen met o.a.:

- Leeftijd
- Geslacht
- Lengte/lichaamsbouw (optioneel, indien relevant)
- Rol in het ziekenhuis, ervaring
- Ooit pijn gehad tijdens het maken van echo's/
- Ervaring met soortgelijke producten (optioneel)

3. Testen van Prototype A (4–5 minuten)

- Deelnemer gebruikt prototype A volgens voorgeschreven gebruik
- Observeren en noteren van gedrag, gezichtsuitdrukking, reacties
- Na gebruik: invullen korte vragenlijst. Schaal: 1 = helemaal niet / zeer oncomfortabel – 5 = helemaal wel / zeer comfortabel

1. Algemeen comfort

Hoe comfortabel voelde het prototype aan tijdens het gebruik?

2. Pasvorm

Sluit het prototype goed aan op je lichaam?

3. Bewegingsvrijheid

Kon je je goed bewegen tijdens het gebruik van het prototype?

4. Drukpunten of irritatie

Heb je tijdens het gebruik ergens drukkpunten, knelpunten of irritatie gevoeld?

5. Materiaalervaring

Hoe prettig vond je het materiaal aanvoelen op je huid?

6. Duurzaamheid (indruk)

Denk je dat je dit prototype de gehele dag comfortabel zou kunnen gebruiken?

7. Ondersteuning

Gaf het product genoeg ondersteuning?

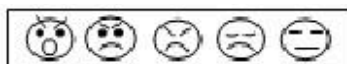
4. Testen van Prototype B (4–5 minuten)

- Zelfde procedure als bij prototype A

5. Vergelijking & afsluiting (3–4 minuten)

- Vragen naar voorkeur tussen de twee prototypes en waarom
- Open feedback of suggesties
- Bedanken voor deelname

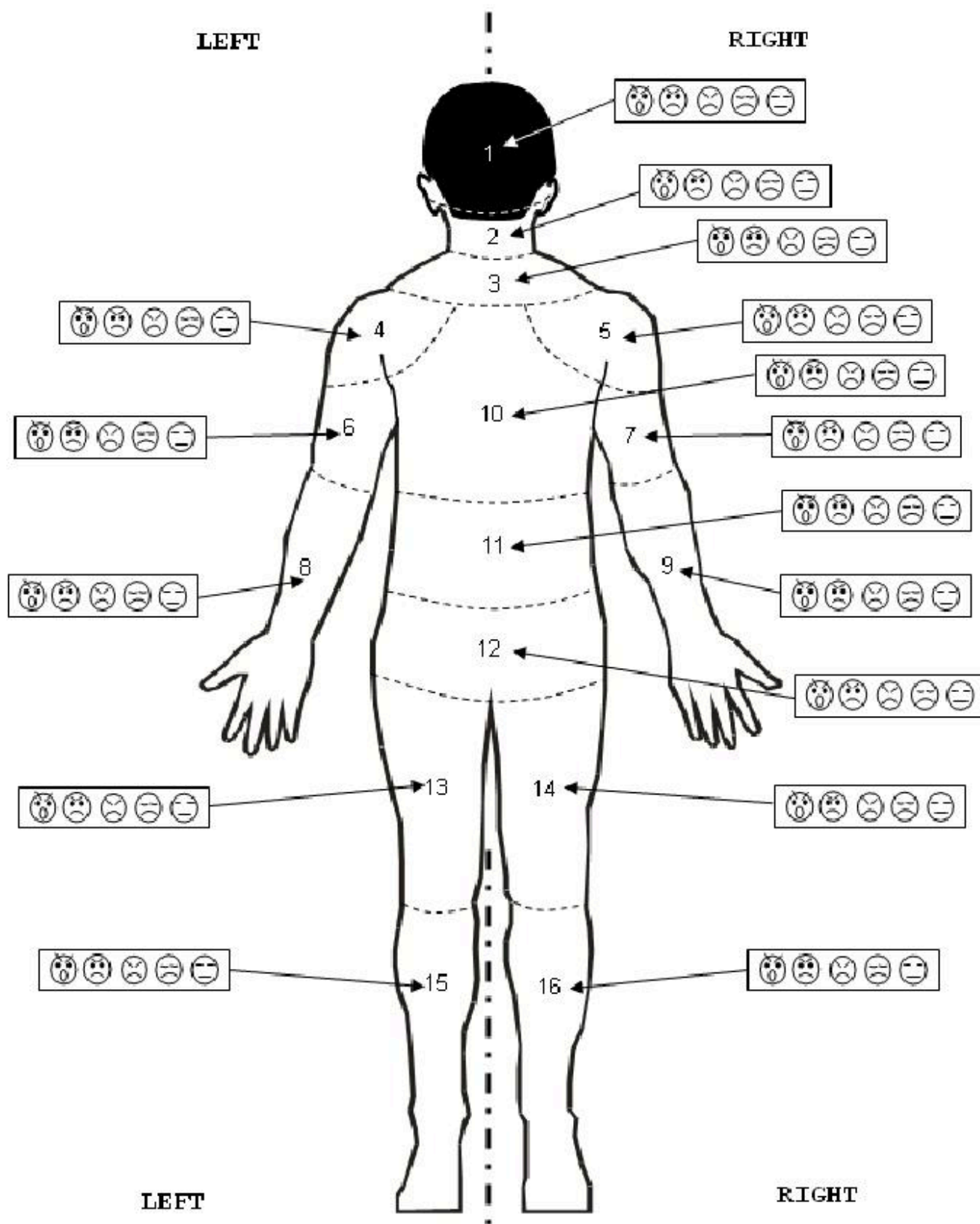
EXTREMELY UNCOMFORTABLE



NORMAL

LEFT

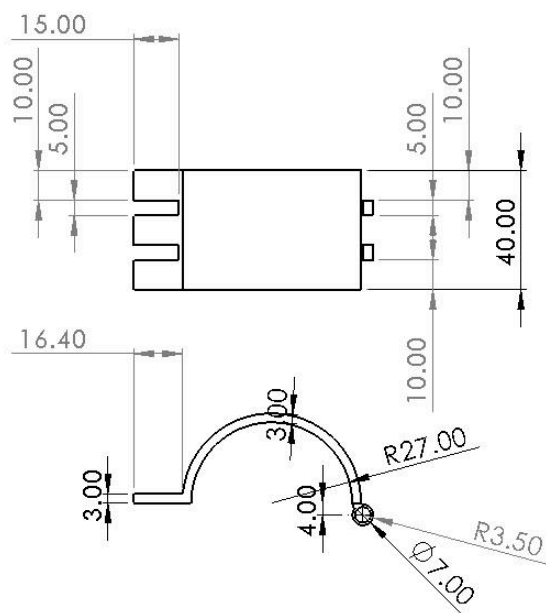
RIGHT



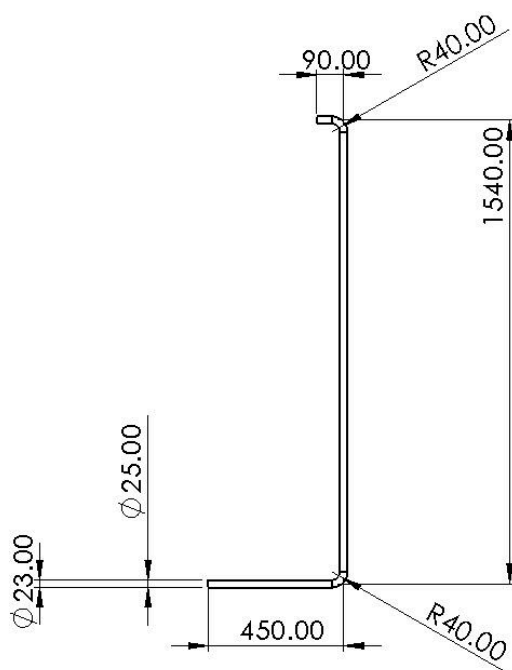
Participant ID									
Datum									
Demografische gegevens				Prototype 1		Schaal: 1 = helemaal niet / zeer oncomfortabel – 5 = helemaal wel / zeer comfortabel	Notities		
Leeftijd				Algemeen comfort		Hoe comfortabel voelde het prototype aan tijdens het gebruik?			
Geslacht				Plasvorm		Sluit het prototype goed aan op je lichaam?			
Langtellichaam bouw (optioneel, indien relevant)				Bewegingsvrijheid		Kon je je alle bewegingen maken die nodig zijn om de echo te kunnen maken?			
Rol in het ziekenhuis, en jaren ervaring				Drukpunt/ irritatie		Had je tijdens het gebruik ergens drukpunten, knelpunten of irritatie gevoeld?			
Doet pijn gehad tijdens het maken van echo's?				Materiaal		Hoe prettig vond je het materiaal aanvoelen op de huid?			
Ervaring met soortgelijke producten (optioneel)				Duurzaamheid		Zou je het product de gehele dag kunnen gebruiken?			
Gewicht 4/-				Ondersteuning		Gefel het product genoeg ondersteuning?			
Linker/rechterhand dig									
nu pijn									
hoogte stoel									
hoogte bed									

Appendix L: Technical drawings

Connection module

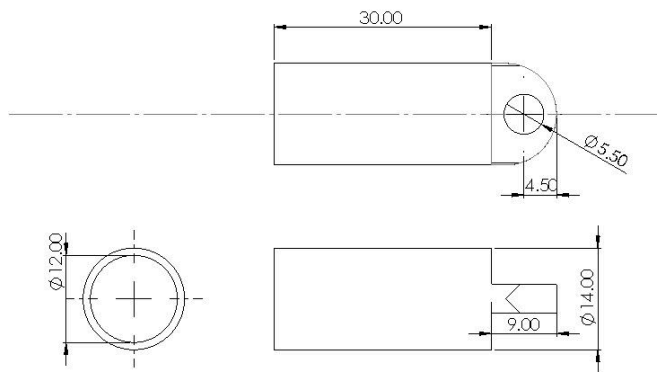


Base module

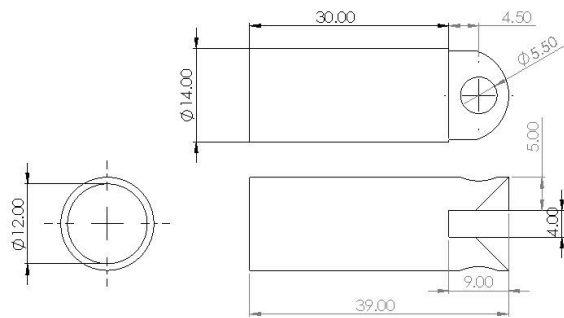


The arch

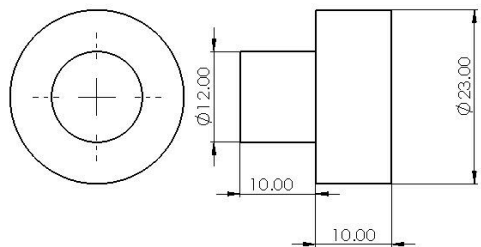
The hinge



Part 1



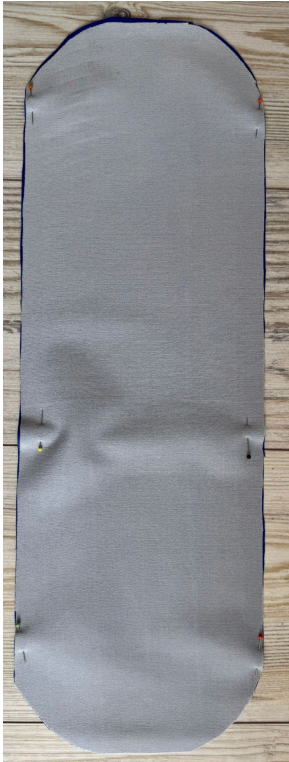
Part 2



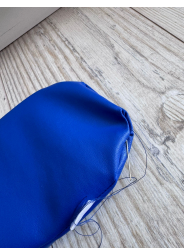
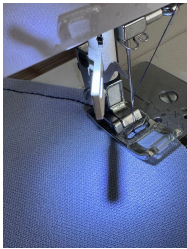
**Spacer hinge and
25 mm**

The sling

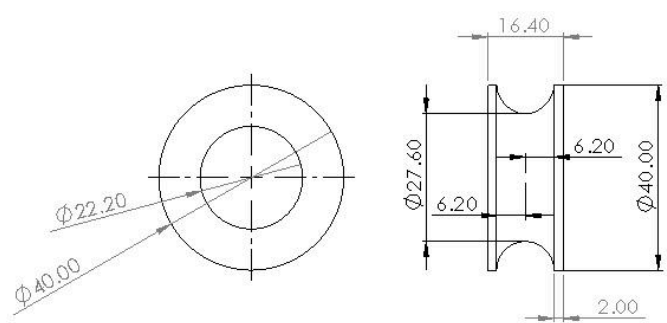
130 mm



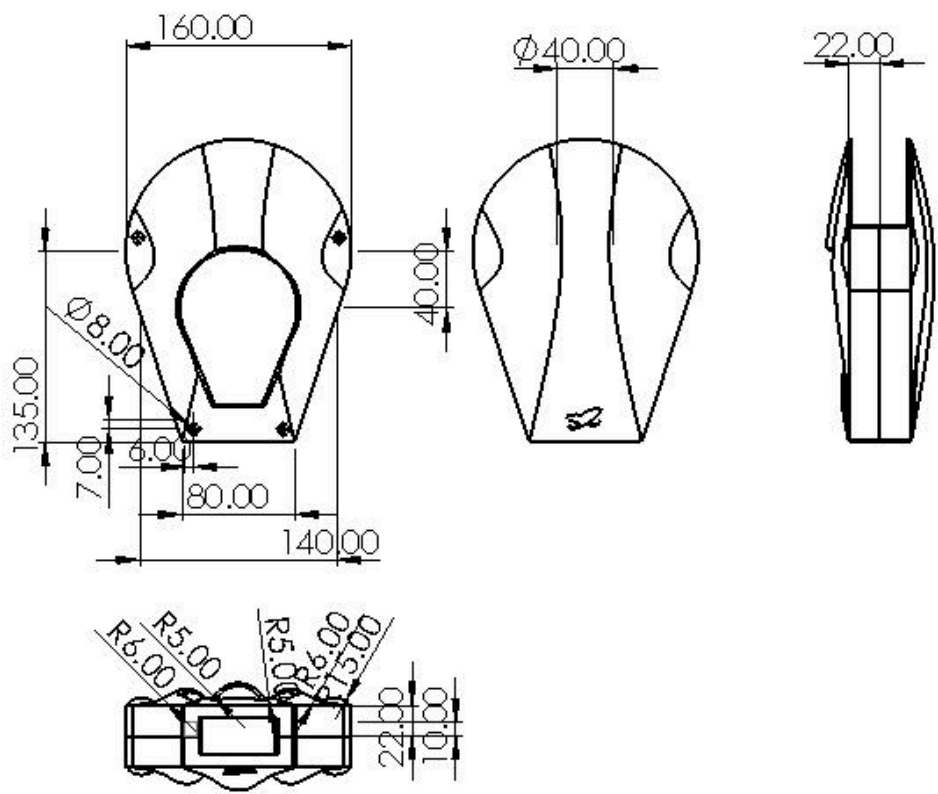
500 mm



Wheel



Spring cover



Appendix M: Setting test

To get an indication of the strength of the spring in the spring base, a relatively simple test was performed. Previously, it was found that the winding of the spring should cover 1.2 kg. With that logic, all sonographers should be able to scan the same patient in the correct height. The 1.5-3 kg spring base should cover this range

A drinking carton was filled with water to exactly 1200 grams (image 1). When attached to the spring, it extended approximately 24 cm (images 2 and 3). Then, the knob was turned several times. After 6 turns (7 modes), the hook came in contact with the base again (image 4). After another turn, it was firmly in place. As the knob has 8 extrusions, this means that we can cover our full range of weights within 1 full rotation, which is promising for the design possibilities.



Appendix N: Button pressed paediatric EMG with Lofius

Results T1 LLD posture

This test registered x points during the full sonograph:

1. Start test (0:00)
2. Change position (00:55)
3. Change position (01:16), moving into position. At 01:20 in this position.
4. Adjusting sling, pressed at 02:00 but happened at 01:53
5. Change position (02:06)
6. Change to supine position (03:32)

Results T1 Supine posture

1. Start test suprasternal view (0:00)
2. Change position (00:55), still suprasternal. At 00:58 in this position
3. change position (01:37), 01:39 in position
4. Change position (01:52), 02:08 in position abdomen. Note: see pole moving away from examination table
5. Change position (02:27), already happened in 02:17
6. Change position (02:43) force position, 02:47 in position
- 02:57 moves backwards to use lofius and still give force
7. sets examination table lower (03:23) to be able to give force
8. End test 03:49

Notes: same strength good for both posture mentioned at position 6 that is gives a little support even when giving force. He mentioned that force comes from the hand/wrist.

Appendix O: Button pressed Gynecology EMG with Lofius

Results T2

This test registered x points during the full sonograph:

1. Start measurement (0:00), lower part belly. Check gender
2. Feeling of pulling away the sling backwards (00:32)
3. Continue to right side of belly (01:02)
4. On top of belly (01:14), belly circumference measure
5. Over half of belly/top of belly (01:44)
6. Top left of belly (01:55)
7. Moving top left of belly (02:14)
8. Right side of belly button (02:32), short but possible position 2
9. Moving from left side belly to bottom (02:40)
10. Spring is moved back to make access bottom part belly easier. (03:13)
11. Bottom belly close to sonographer (03:24). Mentioned that she needs to pull to get it in position.
12. Still bottom belly left side (03:33)
13. Moving arm more above sonographer to make the left side position more easy. (04:21)
14. Back to left side position (04:35)
15. Moving lower still in left side position (05:11)
16. Still left lower side (05:23)
17. Position back to left lower side with different probe (06:12)
18. Move to top belly (07:10)
19. Right top side belly (07:54) (second option for position 2
20. Moment we talk about a moving system for the arm (08:17)
21. Right side belly (08:40), also good option for second position
22. Moving more to top belly (09:21)
23. Right side belly (10:03) also option for position 2
24. Lower side belly right (10:44)
25. Top belly (10:52) (also good option position1 hart instellingen
26. Three vessel view, still just below belly button (14:51)
27. Left bottom side (15:17)
28. Patient was before on left side, now moving back in supine position (16:22)
29. Patient with turned pelvis (16:40)
30. Start after belly muscle contraction (17:09)
31. Lower part belly (17:51)
32. Moving lower middle side belly (18:10)
33. Left side belly on top (19:13)
34. Moving a little lower (19:47)
35. Saying that the sonographer saw everything that was needed for the GUO. (20:41)
36. Patient moved upwards on examination bed, probe on top/right side (20:59) (also good for position two)
37. Far right side, laying arm on patient upperleg, placenta (21:16)
38. Moving along lower line belly to check placenta (21:43)
39. Looking at lips, left close to sonographer (22:04)
40. Still lower left (23:05)
41. Showing position baby and where hands/feet are (23:39)
42. Moving a little (24:38)
43. End of test (25:08)
44. Stop measurements (26:21)

Notes

00:22 mentioning that needs to backwards. gets feeling that you need to pull the sling away.

Position baby: looking at sonographer with head down

4-7 position of sling nicely underneath spring. Use these to compare with posture 1 from former emg test

)2:46 mentioned that if want to go to lower part belly need to work harder to get the arm there due to sling and spring. While in neutral position is it relaxing.

02:57 moving the spring position back

03:55 mentioning this posture is always difficult because turn upper body, also she pulls up her shoulder. Not helping but working against.

05:59 mentioning that on left side of belly force should be lighter. pulling it down with different muscle (more back of arm)

08:07 Moves arm back to middle of belly. In redesign arm needs to move along better.

11:27 Good feeling in this position. I have to lean less on the patient

12:52 patient mentioned that Lofius is not in the way of the view with sonographer or screen.

16:05 patient lays on left side to see if baby will move in different position

16:36 turning pelvis

17:06 harde buik → minder goed kijken

20:05 position 3 with shoulder a little more opgetrokken

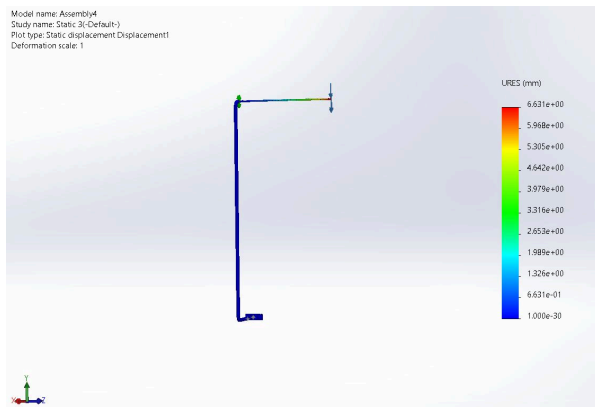
21:10 reaching right side of belly to mimick this position

Has the feeling that neutral position and reaching it gives enough support but close to body and lower she needs to pull. The arm should move along with the horizontal movements of the arm of the sonographer.

Finds the material nice and comfortable. Feel good!

Appendix P: FEM Analysis

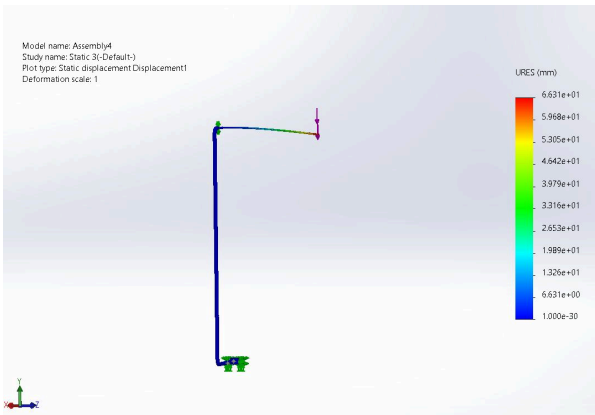
6 Newton



Reaction force (N)

Component	Selection	Entire Model
Sum X:	0.	1.647E-15
Sum Y:	0.	6
Sum Z:	0.	2.9752E-15
Resultant:	0.	6

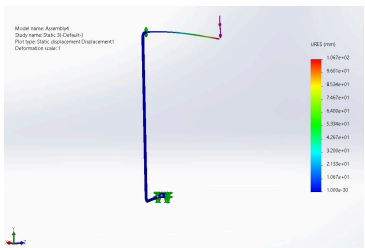
60 Newton



Reaction force (N)

Component	Selection	Entire Model
Sum X:	0.	1.647E-14
Sum Y:	0.	60
Sum Z:	0.	2.9752E-14
Resultant:	0.	60

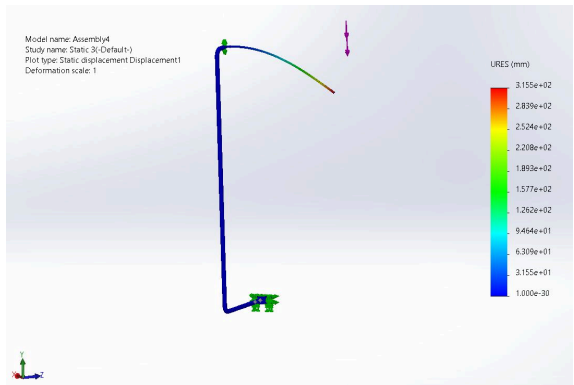
100 Newton



Reaction force (N)

Component	Selection	Entire Model
Sum X:	0.	4.2141E-14
Sum Y:	0.	208.66
Sum Z:	0.	-546.08
Resultant:	0.	584.58

350 Newton



Reaction force (N)

Component	Selection	Entire Model
Sum X:	0.	1.3791E-13
Sum Y:	0.	602.55
Sum Z:	0.	-1,645.5
Resultant:	0.	1,752.4

Appendix Q: LOR

Category	Requirement	CH Ref	Met?
Functional Capabilities	Support patients in lateral (LLD) and supine positions across paediatrics and gynaecology	CH 2.2	Lofius can be used in both positions due to the flexibility provided by the sliding system and hinge.
	Allow probe movement: rocking, tilting, fanning, vertical	CH 2.1	Due to the spring system, no movements are limited
	Compatible with various exam beds, including changing mats	CH 2.2	Not limited by the exam bed as it is placed on the chair. Lofius does not interfere with the changing mat as the support comes from above.
	Design does not obstruct pillow placement under the patient	CH 2.2	The patient is fully accessible from the sides.
	Allow the patient to lie close to the user without obstruction	CH 2.2	Because the support comes from above, the patient can lie as close to the sonographer as possible.
	Enable the user to assist with both hands in emergencies	CH 4.2	The sling is not locked onto the arm, making it possible to respond in emergencies.
	Support the arm in all outer postures and provide movement. - Arm movement range: sideways $\geq$ 466 mm/508 mm, forward/backwards $\geq$ 380–612 mm - Support static and dynamic movements	CH 2.2	The sliding system and hinge provide the flexibility to support the arm in all outer postures and allow the arm to move within its range.
	Allow the patient to lie their arm alongside their torso	CH 2.2	The support comes from above, not limiting the patient's arm placement.
	Not limit the clinician's ability to apply force	CH 2.2	It is still possible to apply force because the sling is placed near the elbow, giving the ability to tilt the arm to apply force.
Workflow & Usability	Minimise added time for sonography	CH 4.3	The only extra time that is added is to set the strength of the spring.
	Minimal setup time and a few user actions	CH 4.3	Because Lofius is placed on the chair, the only steps to take are to set the strength of the spring

			and to put the arm through the sling.
	Easy to align and quick to adjust	CH 4.3	Alignment of the sling underneath the spring goes automatically due to the sliding system.
	Flexible design for posture/workflow transitions	-	The sliding system and hinge provide the flexibility to support the arm.
	Does not block the clinician's monitor view	CH 4.1	No parts of Lofius are in front of the sonographer, blocking the view.
	Supports right-hand gel placement for paediatrics	CH 2.2	The right hand can still be used to put gel on.
Ergonomics & Comfort	Does not restrict movement or obstruct blood flow	CH 4.1	The width of the sling is made to divide the pressure and not restrict the blood flow.
	Accommodates a wide body range, including large breasts	CH 4.1	All body types can use Lofius. The sling is made to fit a variety of users.
	Reduces the need to lean on the patient	CH 2.2	Less patient contact is necessary because the user can lean into Lofius.
	Supports natural working posture	CH 4.1	Lofius does not force the user into an unnatural posture. The resistance of the spring will be heavier in extreme postures. This functions as a reminder not to stay in this position.
	Adjustable for 20th–80th percentile users	CH 4.1	The different settings are designed for p20-80, as well as the width of the sling
Safety & Durability	Withstands the force of ≥ 350 N	CH 4.1	Lofius can withstand this, but this results in a bending of 30 cm, which is not ideal.
	Durable for rough clinical use	CH 4.1	AISI 316 is chosen for its durability. The spring can be easily accessed, making it repairable.
	Perceived as stable, safe, and reliable	CH 4.1	The diameter of the base module is chosen to be the same as other reliable products in the hospital.
	A spring mechanism is guided to prevent overextension	CH 4.3	The table on the user's side guides the sonographer into what setting needs to be used.
	Heat-resistant (for use near heating lamps)	CH 2.2	The stainless steel is. The spring base cover should be further developed.

Hygiene & Maintenance	Made of materials cleanable with water/alcohol wipes	CH 4.3	AISI 316 is easily cleanable, as well as the 3D printed parts. The spring base cover should be iterated to make it less likely for dust to enter.
	Maintenance can be done in the hospital	CH x	Production and maintenance can be done in the hospital.
Spatial Efficiency	Does not obstruct walking paths or movement	CH 4.1	Due to attachment to the chair, limited space is taken.
	Compact design, usable in multiple rooms	CH 2.2	Lofius can be easily moved between rooms.
	Mobile and usable in baby/child paediatric setups	CH 2.2	Because Lofius is attached to the chair, the alternation between setups is no problem
Physical & Material Design	Soft, skin-friendly contact points; no sharp edges	CH 4.1	The edges of the spring base cover are all rounded off, and the sling is made of soft material. The end of the arm is covered.
	Materials do not stick/ to irritate skin; usable with short sleeves	CH 4.3	Priority was now with cleanable material, but more research can be done in looking into other materials.
Visual & Emotional Design	Maintains face-to-face contact between the clinician and parents	CH 2.2	Eye contact between the sonographer and the patient is still possible.
	Uses calming colours and a friendly appearance	CH 5.3	Blue and white are used. Rounded shapes make Lofius appear friendly.
	Avoids harsh noises like metal-on-metal	CH 5.3	The diabolo wheel is made out of POM to avoid the harsh noises.
	Introduced with a name/story/interactive element to reduce child anxiety	CH 5.3	Lofi the hot air balloon will be introduced with a small story to get the child familiar with the product.
Business Constraints	Max price: €500	CH x	When produced in-house, the price will be below €200.