# CHAIRLESS CHAIR EXOSKELETON

## WORK-PHYSIOLOGICAL-BIOMECHANICAL ANALYSIS OF THE LOWER EXTREMITIES


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# I Abstract

Standing work is associated with increased risks of venous and musculoskeletal disorders; particularly low back pain is commonly reported in prolonged standing work. In manufacturing work, work-stations often do not allow standing aids due to insufficient functional and spatial conditions. In 2014, the car manufacturer Audi introduced the lower leg exoskeleton developed by Noonee to their employees working in the factories. This exoskeleton, the 'Chairless Chair', has the advantage that standing work can be performed while technically sitting on this device. The exoskeleton offers the potential for reduced awkward body postures, but it is unclear which biomechanical loads are influenced and how. This study will evaluate the 'Chairless Chair' in a laboratory setting, by testing its effectiveness in terms of biomechanical parameters, including postural balance, back and neck curvature, and muscular activity of selective muscles. For this purpose, different work settings will be compared, consisting of a mixture of different working heights and different positions (wearing or not wearing the exoskeleton) while performing simulated assembly tasks. The study population will consist of 42 healthy men in the age of 18-40 years old, who will perform 7 different experimental conditions.

# II Keywords

Exoskeleton, manual materials handling, musculoskeletal disorders, postural balance, standing work

## Table of Content

# 1 Abbreviations

| | |
|---|---|
| ARV | Average Rectified Value |
| COG | Center Of Gravity |
| COM | Center Of Mass |
| COP | Center Of Pressure |
| EMG | ElectroMyoGraphy |
| FSA | Force Sensing Array |
| IED | Inter-Electrode Distance |
| L3 | Lumbar vertebra 3 |
| MdPF | Median Power Frequency |
| MnPF | Mean Power Frequency |
| PPI | Pressure Peak Index |
| RMS | Root Mean Square |
| RPD | Rating of Perceived Discomfort |
| % RVC | Percentage of Reference Voluntary Contraction |
| SD | Standard Deviation |
| T3 | Thoracic vertebra 3 |
| UKT | [Universitäts Klinikum Tübingen] |

# 2 Background

Standing work is associated with an increased risk of venous disorders (Sudol-Szopinska et al. 2011: Ziegler et al. 2003) and musculoskeletal disorders (Werner et al. 2010). Particularly low back pain is a commonly reported disorder in prolonged standing work (Andersen et al. 2007; Gregory and Callaghan 2008). The development of lower limb discomfort is mainly the result of stationary standing, and to a lesser extent of dynamic standing (Balasubramanian et al. 2009). Some studies suggested using aids during standing work to relieve the load of the back muscles and reduce symptoms; however, not every workplace allows the use of standing aids because functional and spatial conditions are insufficient.

One solution to reduce the exposure of employees to associated risks for developing work-related musculoskeletal disorders is to use exoskeletons. Using such devices in dynamic environments has the advantage over, e.g., robotics because it does not need any programming or teaching of robots. Moreover, exoskeletons are worn on the body and do not have to overcome spatial issues. In a recent review, 26 different exoskeletons have been described of which only two were designed to support the lower body during heavy work (de Looze et al. 2015). For low-intensity work, like assembly work in the automobile industry, no study has focused on using exoskeletons to relieve employees while performing the work standing.

Since 2014, Audi has several passive exoskeletons to use in their production lines and factories in Southern Germany, where employees perform different types of assembly work while standing (Feigl 2015; Karius 2015; Stirnemann 2015). The passive exoskeleton, the ‘Chairless Chair’, provides support for the lower extremities. The system is developed by the Swiss company Noonee (Saameli 2014). The ‘Chairless Chair’ offers the potential for a reduction of awkward body postures, even in restricted spatial conditions at standing workplaces. It is unclear which physiological and biomechanical loads are influenced by the 'Chairless Chair' exoskeleton and how. Furthermore, it is not clear whether participants of all body heights will experience the same beneficial effects, if any, when wearing the system.

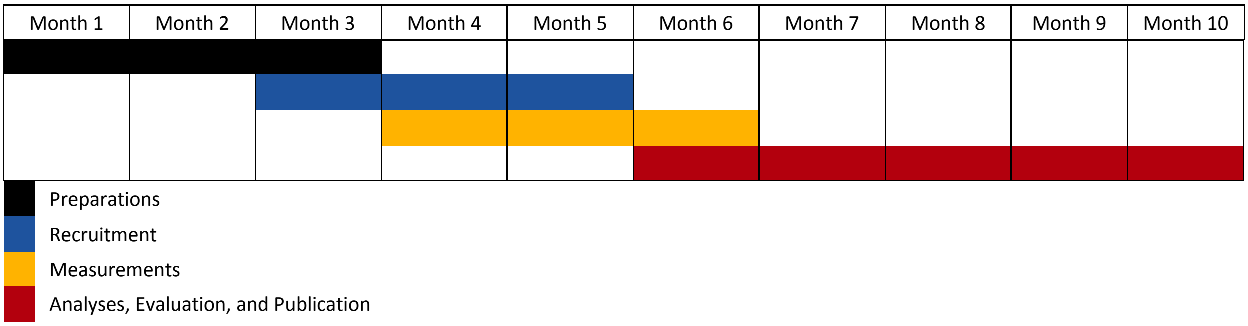
## 3 Objectives

This research proposal aims to provide a sophisticated study design in which participants simulate assembly work related to that performed in the Audi factories. With measurements of several physiological and biomechanical parameters, work-physiological-biomechanical analyses will be performed to investigate the influence of wearing the exoskeleton during assembly tasks. The participants included will be grouped according to their body height, enabling us to investigate whether body height influences the effectiveness of wearing the exoskeleton.

## 4 Timetable

The project consists of four phases (Table 1). First, the study design and measurements need to be prepared, which will take approximately three months. Participants will be recruited during three months and the measurements will take up to three months. The data analysis, evaluation, writing and publication will be spread over five months. The four phases will be performed with some overlap with a total length of the study of about ten months.

**Table 1**. The timetable for the proposed study that will be completed early 2018.




## 5 Study Design and Study Population

### 5.1 Study Design

The laboratory study will include several experimental conditions, being a combination of supported seating or unsupported standing by the exoskeleton, and three different working heights. These seven combinations will be offered to the subjects in a balanced, randomized cross-over design (Latin Square Williams Design; Williams 1949). In each of these seven conditions, three manual materials handling tasks will be simulated in a fixed order but in three different frontal working distances. Because of the three working distances, we will include a multiple of the 14 orders resulting from the Williams Design, striving for a population of 42 subjects.

### 5.1.1 Independent variables (within-subject factors)

At first, experimental conditions are designed by a combination of working position and working height. We will investigate three different working positions [P]: (1) unsupported standing [US], (2) supported high seating [HS], and (3) supported low seating [LS]. We will investigate three working heights [WH]: high [H], medium [M], and low [L]. The combination of these two independent variables is displayed in Figure 1A. The randomized design for assigning conditions to subjects will be based on an orthogonal Latin Square Design (Figure 1B). A third independent variable considered is working distance, i.e. the distance of the task set-up from the front of the subject: (1) optimal, (2) far, (3) very far; the order of these three working distances will also be varied by assigning them balanced to the subjects. For the order of the three working distances, the outcome of a special type of Latin Square Design, the Williams Design suggests three different orders (for the complete experimental design, see Attachment 8).

| A | $WH_H$ | $WH_M$ | $WH_L$ |
|---|---|---|---|
| $P_{SS}$ | V | V | X |
| $P_{HS}$ | V | V | V |
| $P_{LS}$ | X | V | V |

| B | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | B | C | D | E | F | G | D | E | F | G | A | B | C | A | $P_{SS}WH_H$ |
| 2 | G | A | B | C | D | E | F | E | F | G | A | B | C | D | B | $P_{SS}WH_M$ |
| 3 | B | C | D | E | F | G | A | C | D | E | F | G | A | B | C | $P_{HS}WH_H$ |
| 4 | F | G | A | B | C | D | E | F | G | A | B | C | D | E | D | $P_{HS}WH_M$ |
| 5 | C | D | E | F | G | A | B | B | C | D | E | F | G | A | E | $P_{HS}WH_L$ |
| 6 | E | F | G | A | B | C | D | G | A | B | C | D | E | F | F | $P_{LS}WH_M$ |
| 7 | D | E | F | G | A | B | C | A | B | C | D | E | F | G | G | $P_{LS}WH_L$ |

**Figure 1**. A. Incomplete Block Design (Williams Design) based on position (P) and working height (WH), resulting in 7 different experimental conditions; B. Latin Square Design for 14 subject, which will be preferably elongated to a replicate of 14 subjects.

We consider three fixed working positions for each subject, standing, high seating and low seating on the Chairless Chair. According to the anatomy of the individual, the optimal working height for each working position can be calculated (Equation 1; in accordance with DIN EN ISO 14738:2009-07). Optimal working heights in Figure 1 correspond to (A) $P_{SS}$ x $WH_H$, (D) $P_{HS}$ x $WH_M$, and (G) $P_{LS}$ x $WH_L$, and are based on an optimal elbow angle of 105° with the upper arm vertical alongside the upper body. The non-optimal working heights deviate -10% and +10% from the optimal working height. In a similar way, the optimal working distance (WD) with respect to the subject (in accordance with DIN EN ISO 14738:2009-07) is calculated (Equation 2) and the non-optimal working distances deviate +15% and +30% from the optimal working distance.

$$WH_{optimal} = length_{elbow-floor} - \left(\sin(\alpha) \cdot length_{elbow-grasping\ hand}\right) \quad \textbf{Eq. 1}$$

$$WD_{optimal} = \cos(\alpha) \cdot length_{elbow-grasping\ hand} \quad \textbf{Eq. 2}$$

with α the angle (°) with the horizontal position of the lower arm, which is always 15°.

## 5.2 Study Population

We will select male participants with a body height corresponding to the average German body height of the working population aged 18-40 years old. We will recruit males only, because most assembly work at Audi is performed by men. In 2013, German males were on average 180.6 (SD 7.3) cm tall (Statistisches Bundesamt 2015).

## 5.3 In- and Exclusion Criteria

Inclusion criteria (Attachment 2):

- Age between 18 and 40 years;
- Male gender;
- The participant will give his voluntary informed consent after receiving oral and written information of the content and goal of the study.

Exclusion criteria (Attachment 2):

- Aged <18 and >40 years;
- Female gender;
- People under the influence of intoxicants, analgesics, or muscle relaxants;
- Alcohol abuse;
- People with cardiovascular diseases;
- People with a heart pacemaker;
- People with a disability who, due to their restriction at a workplace of this kind, will not be able to participate;
- People with Diabetes Mellitus;
- People with severe muscle contractions of the lower extremities, back or arms;
- People with acute ailments or pain;
- People who are unable to complete the examination program due to language or cognitive obstacles;
- Depending on the degree of severity, people with diseases of the veins and joints of the lower extremities, spine, muscle disorders, symptomatic neurological-psychiatric diseases, acute pain syndromes, maladies or other current diseases.

## 5.4 Recruitment

Volunteering participants will be recruited by means of an announcement e-mail at the University Hospital Tübingen, the Eberhard-Karls-University Tübingen, as well as by e-mail to former participants who agreed to be informed about future studies (Attachment 7).

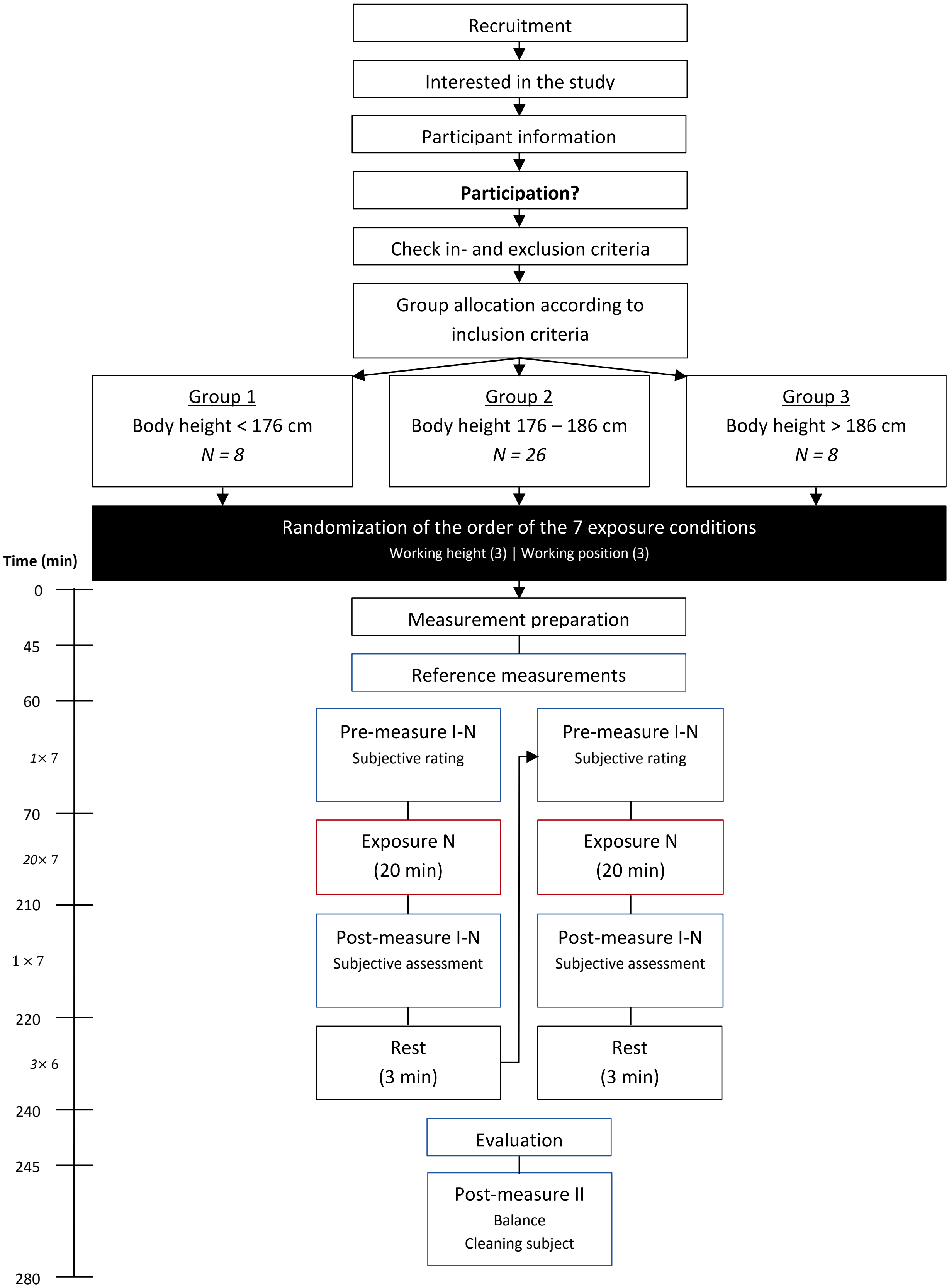



**Figure 2**. Study course. During the exposure, posturography, muscle strain and work performance will be continuously recorded.

### 5.5 Sample Size

The planned study serves as a pilot study for a future larger research project and is intended to provide, among other things, the basis for a concrete calculation of the number of cases for follow-up projects. For this reason, and considering that we will include 7 experimental conditions with 3 working distances, we think that 21 individuals is the minimum for evaluating the exoskeleton, but we strive for 42 to have a double balanced randomization controlled cross-over design (double Williams Design). The total study population will be divided, based on body height, in three subgroups (Figure 2). The groups are based on (1) < 25$^{th}$ percentile, (2) 25$^{th}$ to 75$^{th}$ percentile, and (3) > 75$^{th}$ percentile of the average body height of 18-40 German males. As a result, the subgroup analyses may statistically be somewhat weaker than the overall statistical assessment of 42 participants.

We are mainly interested in recruiting men that fall in between the 25$^{th}$ and 75$^{th}$ percentile of the average German body height distribution, corresponding to Group 2 (Figure 2). The percentiles can be calculated using the formula: $X = \mu + Z \cdot \sigma$, in which $\mu$ is the population's mean, $Z$ the *z*-value belonging to the desired percentile, and $\sigma$ the population's standard deviation.

## 6 Study Procedure

### 6.1 Experimental Procedure

Before the experiment starts, participants will visit the lab for familiarization with the 'Chairless Chair' and familiarization with the three manual materials handling tasks. They will perform the simulated assembly tasks for about 30 to 45 minutes, of which 15 to 30 minutes while wearing the exoskeleton (3.8 kg) in the different positions. During this first visit, the subjects will also complete the form with general information (Attachment 1), the form with in-/exclusion criteria (Attachment 2) and will be explained in a standardized way about how to report and judge subjective feelings of discomfort (Attachment 3). After familiarization, participants will visit the laboratory a second time during which they will perform the seven experimental conditions (exoskeleton [3], working height [3]) in a preset balanced randomized order (using a Williams Design). Before starting with the true experiment, participants will first be equipped with the measurement devices. After the preparations, participants will perform each experimental condition for ~20 min followed by 3-min rest breaks. During the rest break the participant will first walk around and then sit down with wearing the exoskeleton.

After finishing the experimental conditions, subjects will perform 11 trials on the force plate. Two trials will be performed while the subject is wearing the exoskeleton and is standing (1) with only his feet on the force platform while the feet of the 'Chairless Chair' are off the force platform. The trials will be recorded while in low seating and in high seating when wearing the exoskeleton and performing one work cycle in optimal height. These trials should provide insight into the body weight distribution over the own feet and the exoskeleton. Nine other trials will be performed to provide insight into the center of pressure's behavior when performing tasks in different lateral workspaces. The nine trials will include three different positions (unsupported standing, supported high seating, supported low seating) and three different frontal-lateral workspaces (narrow in a range of 120°, intermediate in a range of 150°, and broad in a range of 180°). The order of the three positions and the three workspaces will also be randomized using a Williams Design for nine combinations of position and workspace (Attachment 8). Finally, the subjects will evaluate the exoskeleton by filling out a questionnaire. During the tasks, posturography, muscle strain and work performance will be continuously recorded (Figure 2).

## 6.2 Experimental Tasks

The simulated assembly tasks shall represent the existing assembly tasks at the automotive factories of Audi, including screwing, clip fitting, and cable mounting. The three tasks are presented to the subject on each side of a triangle (2.7 kg; Figure 3). One full work cycle consists of assembling the three subtasks and disassembling the three subtasks: (1) assembling 4 screws with an electrical screw driver, (2) fitting two rows of five clips, (3) mounting three cables to one coupling piece, (4) disassembling 4 screws with an electrical screw driver in reverse, (5) loosen the clips, and (6) loosen the cables to remove the coupling piece. We expressed the task, i.e. the work cycle, in codes of the predetermined motion-time system MTM-1 (Maynard et al. 1948). This system is often used in industry to assess the work pace, which also applies to Audi factories. Using detailed tables of the MTM-1 system, we are able to calculate the MTM-100, the pace corresponding to the work pace that a regular worker should be able to reach. Although Audi strives to work at pace MTM-114 at its factories, we strive for pace MTM-100, which is equal to ~80 s per work cycle (for an extensive determination of the MTM-pace, see Attachment 9). A metronome including both visual and auditory feedback will be provided to set this work pace for the simulated assembly tasks, indicating how much time the participant has left in a work cycle (the visual feedback is in accordance with Audi factories, in which employees are shown how much time is left to finish the work cycle in the green, orange or red zone).

During the balance measurements after the experiment performed at the force platform, a n auditory metronome will be set for determining the pace at which subjects should move a 2-kg weight from the one side to the other.

**Figure 3**. Three manual materials handling tasks. One work cycle consists of assembling the screws, clips, and cables and also disassembling them.

# 7 Data Collection

Objective data collection includes that of posturography, muscle strain, and work performance; subjective data collection includes feelings of discomfort and an evaluation questionnaire about working with the exoskeleton. All measurement devices are CE certified and data will be collected by researchers familiar with the measurements devices, data extraction, and pseudonymization.

## 7.1 Anthropometry

At their first visit to the laboratory, participants will be asked to provide us with their anthropometric data including their age, body height, and body weight. This information will be documented together with the length measurements of several body parts (Attachment 1).

## 7.2 Posturography

The study of Lafond et al. (2009) showed that low back discomfort is more prevalent when people make fewer postural adjustments during stationary standing. This means that posturographical analyses may provide information about postural control mechanisms related to low back discomfort. For this purpose, we should include both the lower limbs and trunk because they cooperate with each other when stabilizing a working posture (Leyman et al. 2001). This became particularly clear by a recent study, in which participants had to maintain their postural balance while standing on a narrow unfixed base of support (Mani et al. 2016). With practice, the distance between center of pressure (COP) and the projection of the center of mass (center of gravity, COG) decreased, while the motion of the lower extremity did not change. This result shows that our body is highly redundant and indeed controls postural balance with strong intersegmental cooperation.

When registering and reporting on posturography, both limb motions as well as balance control are two important and interrelated concepts. Limb motions define the control of the postural balance, including concepts as center of pressure (COP), center of gravity (COG; Figure 4). The COP is the point where the resultant of all ground reaction forces act. The center of mass (COM) is the point where all the mass of a body is concentrated. The COG is the vertical projection of the center of mass to the ground, when one is on earth within the gravitational force field.

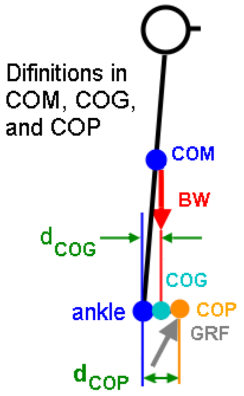



**Figure 4**. The figure illustrates the most important concepts related to postural balance in sagittal view, including the center of mass (COM), the center of gravity (COG), and the center of pressure (COP). Source: http://www.pt.ntu.edu.tw/hmchai/BM03/BMClinic/Stance.htm.

Dynamic stability, representing postural control, can be tracked by having participants stand on a force plate (Type 9287CA, Kistler, Toronto, Canada) while working. When assuming that the placement of the feet is known, the force plate can record the pressure distribution in the known area using a transformer (DAQ-System, Type 5691A1, Kistler, Toronto, Canada) which allows us to track the COP in the anterior-posterior and medial-lateral directions (BioWave, Kistler, Toronto, Canada).

Joint motion will be recorded using gravimetric position sensors (THUMEDI, Thum-Jahnsbach, Germany) which have a resolution of 0.1° and 125 ms in time, and a maximum static error of 0.5°. The sensors will be attached to the lumbar spine at the third lumbar vertebra (L3), the thoracic spine at the third thoracic vertebra (T3), and at the forehead. After calibration, each sensor measures its inclination angle with respect to the absolute perpendicular (gravitational axis) in the anterior-posterior (flexion) and medio-lateral (lateral flexion) directions. The difference between the flexion angles of the sensors at L3 and T3 results in the curvature of the spinal column; the difference between the flexion angles of the sensors at T3 and the forehead results in the neck flexion/extension angle.

## 7.3 Muscular Stress and Strain

During standing work, evaluation of the exoskeleton also includes assessing the level and development of muscle activity in selected muscles. Furthermore, it might also be interesting to investigate whether wearing or not wearing the exoskeleton is associated with any manifestations of muscle fatigue. Activity of selective muscles at the legs, back, and shoulders will be recorded. In the lower leg, the Gastrocnemius Medialis is involved in knee bending. In the upper leg, the Vastus Lateralis contributes to standing by supporting the knee and hip. At the lower back, the Erector Spinae Lumbalis helps holding up the spine. At the shoulder region, the Trapezius Descendens is one of the prone muscles during manual materials handling and is responsible for scapular movements and supports arm movements.

Activity of the muscles will be tracked continuously during the experiment using surface electromyography (EMG). This method uses recording electrodes (42×24 mm, Kendall™ H93SG ECG Electrodes, Covidien, Zaltbommel, the Netherlands) that are attached to the skin's surface overlaying the muscle of interest with an inter electrode distance (IED) of 25 mm. The differential signal (bipolar derivation) of two electrodes placed over one muscle belly, recorded by an amplifier (PS12, THUMEDI® GmbH & Co. KG, Thum-Jahnaback, Germany), gives a firm estimation of that muscle's electrical activity in microvolts (µV). This electrical activity pattern enables us to estimate the magnitude of the muscle activity (amplitude) and the overall firing frequency of the muscle (power frequency). The amplitude can be calculated by the overall root-mean-square (RMS) of the power spectrum of the EMG signal. The median power frequency (MPF) can be calculated from the power spectral density of the EMG signal by calculating the median.

## 7.4 Reference Measurements

Before starting with the experiment and measurements, we need reference recordings for posturography and muscle strain. For the postural reference, the participant will stand upright with his back straight, his arms alongside the body, and hand palms facing forward. While the participant is standing in this position against a vertically levelled wall, a recording will be saved. The joint angles from this reference recording represent all the zero angles, which can be used for referencing.

Muscle strain, as measured by EMG, will be normalized to a submaximal reference contraction. Each muscle that will be recorded has its own reference contraction and submaximal force level (Table 2; Coorevits et al. 2008). The posture during the reference contractions is continuously judged by one of the experimenters. After the reference contractions, the participant is provided with a short period of rest to recover from the exertions. The reason for this submaximal reference contraction is to normalize the EMG signals and decrease the variance between subjects. The measured muscle activity levels are, therefore, expressed as a percentage of the submaximal reference voluntary contraction (% RVC).

**Table 2**. Body segments with muscles of interest for investigating muscular strain while assembling. The reference contractions are performed for 30 s and the reported angles represent flexion angles (see also Figure 5).

| Segment | Muscle(s) | Reference voluntary contraction | Force level |
|---|---|---|---|
| Lower legs | Gastrocnemius Medialis | Lay prone, 90° hip, 90° knee, foot neutral (90°), hold position (with strap with weight around toes) | 10 kg |
| Upper legs | Vastus Lateralis | Lay supine, 90° hip, 90° knee, hold position (with weight hanging just ventrally over ankle) | 5.0 kg |
| Lower back | Erector Spinae Lumbalis | Lay prone, 0° hip, 0° knee, horizontal back extension with arms crossed on the chest, upper body off the bench and the legs fixed with straps | Weight upper body |
| Shoulders | Trapezius Descendens | Standing upright, arms 90° flexed upward, 0° elbows, holding weight in both hands | 1 kg |

**Figure 5**. Reference contractions for EMG normalization for the four muscles: (left up) vastus lateralis; (right up) gastrocnemius medialis; (left down) trapezius descendens; (right down) erector spinae lumbalis (see also Table 2).

## 7.5 Work Performance

Useful information for industry is work performance with respect to wearing the 'Chairless Chair' exoskeleton. We will continuously track the error rate, which represents a mistake made during the assembly process. Also, the timing error will be registered, which is defined as the wrong timing with respect to the metronome (Bosch et al. 2012). When the participant is faster than the metronome, this is a positive timing error; when the participant is slower than the metronome, this is a negative timing error.

Bitte geben Sie die Intensität des aktuellen Beschwerden auf einer Skala von 0 (kein Beschwerden) bis 10 (schlimmste Beschwerden vorstellbar) an.

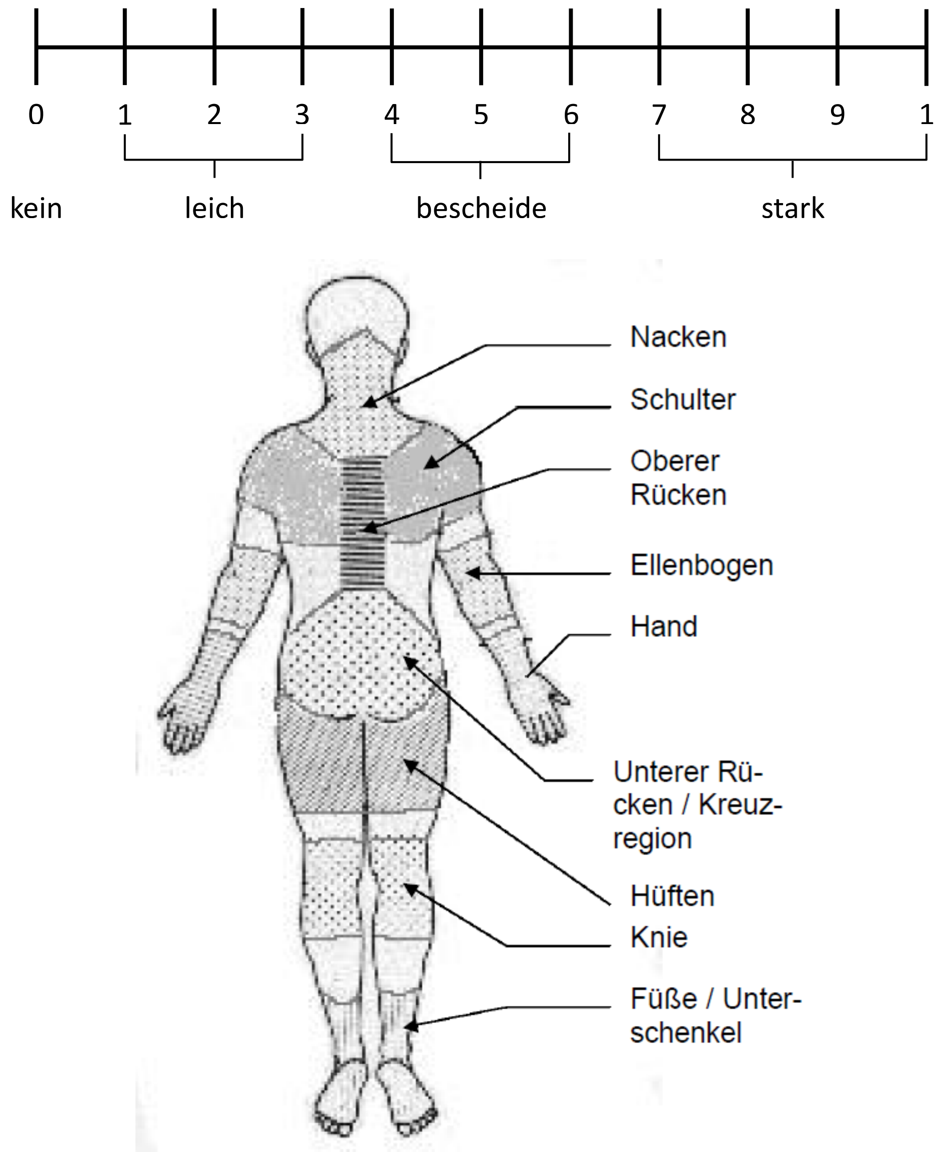



**Figure 6**. The 11-point numerical rating scale (McCaffery & Beebe 1989) and body map (Kuorinka et al. 1987) as used in this study.

## 7.6 Subjective Assessment

Participants will rate their overall subjective feeling of discomfort (RPD) on a 11-point numerical rating scale (McCaffery & Beebe 1989; Figure 6; Attachment 3). When participants experience a feeling of discomfort > 0, we ask them to define the body region (Kuorinka et al. 1987) which is causing this sensation.

### 7.7 Participant Evaluation

When the participants have finished the experiment, we will provide them with a short questionnaire to report their opinion about using the exoskeleton for the various experimental conditions. This will provide us information about the acceptance of the worker regarding the use of the 'Chairless Chair'. The questionnaire will include items on feasibility, comfort, and usability (Attachment 6).

## 8 Statistical Analysis

When all data are collected, we will have a number of dependent variables as listed in Table 3. Each of these parameters will provide a(n) (average) value per condition, resulting in four values. For the continuous measurements, i.e. posturography, muscle strain, and work performance, we will average the values over each of the seven conditions. For the discontinuous measurements, i.e. subjective discomfort ratings, we will calculate the difference value of the pre- and post-condition measurements. Participant evaluations will not be tested but only discussed narrative.

**Table 3**. Summary of the model components that will be included in the statistical analyses.

| Model component | Method / Name | Parameter |
|---|---|---|
| Dependent variable | Posturography | Center of Pressure (COP) |
| | | Joint angles |
| | Muscle strain | Amplitude (ARV) |
| | | Median power frequency (MdPF) |
| | Work performance | Error rate |
| | | Timing error |
| | Subjective assessment | Rating of perceived discomfort (Borg RPE) |
| Within-subject factor | Working postures | Without, with (high), with (low) exoskeleton |
| | Working height | High, medium, low |
| | Working distance | Optimal, too far I, too far II |
| Between-subject factor | Group | Body height (S/M/L) |

The current study has a repeated measures design including three within-subject factors (*exoskeleton*, *working height*, and *working distance*). If we have enough participants, we could also include a between-subject factor (*group*, based on body height), or another post-hoc identified discriminator. We will use a linear mixed effects model to perform the statistical analyses of all dependent variables (Table 3) using SPSS (IBM SPSS Statistics 23.0). This model allows observations to be not independent, because it adds a *random effect* for subject, i.e. modeled by assuming different *random intercepts* for each subject. This model also allows including both repeated measures, i.e. different conditions (within-subject factor: *working height*, *working posture*, *working distance*), and comparing independent groups of participants (between-subject factor: *group*).

## 9 Risk for the Participant

The experiment has no threatening risks for the participant. However, there can be some side-effects of study-related procedures about which we will inform the participant, including:

- Skin irritation or reddening due to skin preparation and of the attachment of the adhesive electrodes; in rare cases, participants may experience allergic reactions;
- Tingling or tension sensations in the area of the adhesive electrodes due to cable pull;
- Sensations of tension or muscle fatigue along the duration of the experiment;
- Possible sensations of dizziness, loss of blood pressure, and a very low risk of impotence due to the semi-standing for a total of 70 minutes.

## 10 Data Protection

The participants as well as their personal and recorded data will be numerically pseudonymized by assigning a randomly generated, five-digit identification number to the examined participant. Relating analyzed outcome data to the natural person is only possible by inspection of the decoding list. This list, together with the informed consents of all volunteering participants, will be stored separately from the measured data in the storage of the Institute of Occupational and Social Medicine and Health Services Research. All these participant data will be stored for a period of ten years after publication of the results. The destruction of the data in paper form is carried out by means of the disposal boxes for data protection at the University Hospital, and the destruction of the data in electronic form is carried out by means of transferring the data off the memory cards of the devices.

The measurements as part of this proposal are all recorded on portable computers that are accessible by means of a password only and cannot be accessed by any network. The pseudomynized data are processed within the University Hospital (UKT) network, of which the time of the measurement collection is removed from the operating software whenever possible. The measuring devices are configured identically for all measurements to exclude a possible association between the measurement configuration and the participants. After completing the data analysis, the data of the participants are stored together with the photo documentation on Blu-ray discs.

Only employees directly involved in the study have access to the data. In addition, all employees of the Institute for Occupational and Social Medicine and Health Services Research who are involved in the study are subject to medical confidentiality.

At the start of the study, participants are asked whether they wish to be informed about the primary results of the study. In case of several interested parties, an information event will be organized for the participants after completion of the data evaluation. If there is only little interest, a brief written presentation of the primary results will be spread and sent to interested parties by e-mail.

## 11 Study Finance

The financing of the study, including personnel costs and costs for technical equipment and assistance, are funded by Audi AG. The volunteering participants will receive a compensation of about € 10 per hour. The two days of testing together take approximately five hours, which results in a total amount of € 50.

## 12 References

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