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Application of Wearable Technologies for the Assessment of an Ergonomic Intervention in Hairdressers: Preliminary Results

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ABSTRACT

Several authors conducted ergonomic risk assessments through standardized protocols, like REBA, founding high-risk levels of hairdressing job. Others measured shoulder and wrist movement with IMU or inclinometer and found a high biomechanical risk. One study used electromyography (sEMG) to investigate flexors and extensors of upper limb to compare the activity of male and female hairdressers founding those women had considerably higher sEMG activity. In our previous study, we investigated the kinematic of the neck, trunk, and upper limb and sEMG bilaterally from Latissimuss Dorsi, Erector Spinae, Trapezius Superior, Deltoideus Anterior, Extensor Carpi Ulnaris, Flexor Carpi Ulnaris in hair drying in two different ways (horizontally – HOR and upwardly - UP). We found a high standard deviation for RoMs, indicating a high heterogeneity in performing the same task. Our sEMG results showed that, in both investigated tasks, the left side of the body was generally more involved than the right one. The right side, the one holding the phone, showed less %MVC mean values than the right side, the one holding the comb. Our sEMG results suggest that handling a 1 kg phone in a static position is less demanding for upper limbs and shoulders than using a light comb in continuous motion. In another paper, we investigated, through REBA and 3DSSPP, the static posture of workers after a corrective action consisting of a hairdryer holder. We found that the holder contributes to changing the posture in either positively or negatively. The positive effects seemed more than the negative ones. In this new paper, we investigated the effect of the hair dryer holder in dynamic situations founding that there are no significative improvements in the biomechanics of the workers. Moreover, the holder seemed to increase several investigated RoMs. The workers also complained of decreased flexibility of the wrist. Our results suggest that the holder system seems to have more negative than positive effects. To reduce the biomechanical overload in hairdryer, we suggest improving several aspects, the training, the equipment (lighter hairdryer and adjustable seats), and increasing the breaks.

Keywords: Ergonomic, Hairdresser, Drying, Electromyography, Kinematic

INTRODUCTION

Evidence of biomechanical overload risk and musculoskeletal disorders (MSDs) in hairdresser activity is widespread all over the world: Nigeria (Aweto, 2015), France (Deschamps, 2014), Ethiopia (Mekonnen, 2019), Norway (Hanvold, 2013), Egypt (Hassan, 2015), India (Kaushik, 2014), Iran (Reza, 2008; Mahdavi, 2014), Sweden (Wahlstrom, 2010).

MSDs in hairdressers are so relevant that even EU-OSHA (Kozak, 2019) determined to focus on this job.

In our previous study (Silvetti, 2023), we investigated the kinematic of the neck, trunk, and upper limb and sEMG bilaterally from Latissimuss Dorsi (LAT), Erector Spinae (ES), Trapezius Superior (TRAP), Deltoideus Anterior (DA), Extensor Carpi Ulnaris (EXT), Flexor Carpi Ulnaris (FLEX) in hair drying in two different ways (horizontally – HOR and upwardly - UP).

The shoulders (TRAP and DA) showed relevant mean %MVC values, particularly in the UP task.

Moreover, in both investigated tasks, the left side of the body was, overall, most involved than the right one, particularly for LAT, TRAP, DA, and FLEX muscles.

The right side, the one holding the phone, showed less %MVC mean values than the right side, the one holding the comb.

Our sEMG results suggest that handling an 850 gr phone in a static position is less demanding for upper limbs and shoulders than using a light comb in continuous motion.

Kinematic data seems to support this.

The shoulder abd-adduction and elevation on the UP task and shoulder horizontal abd-adduction, elbow flex-extension, and wrist prono-supination showed the highest RoM values on the left side than on the right on both tasks.

The shoulder flex-extension showed similar overall high RoM values.

This last movement of the shoulders was the most relevant as it showed the highest RoM values.

Our results also showed high SD for the RoM, thus revealing high variability in the execution of the tasks in hairdressers despite our extreme standardization.

In another paper (Silvetti, 2022), we used REBA (Hignett, 2000) and 3DSSPP software (Chaffin, 2006) to assess the posture of the worker in the hair drying task before and after an ergonomic intervention consisting of a holder for the hair dryer.

Our static biomechanical data showed that the holder system seemed to reduce risk levels.

With 3DSSPP, we observed posture improvements in the left wrist flexion/extension and ulnar deviation, left shoulder axial rotation of the humeral head, and left elbow flexion/extension.

Also, REBA analysis showed a risk reduction.

When using the holder, the score decreases from 9 to 2 for the left upper limb and from 5 to 2 for the right upper limb than non-using the holder system.

All our previous analysis showed that the holder system seems to reduce risk levels.

This new study aims to verify our previous data in a dynamic working situation through a multifactorial movement analysis based on kinematic and surface electromyography data.

MATERIAL AND METHODS

We acquired four experienced health workers, two women, and two men, with more than ten years of experience (height 168.7±9.1 cm; weight 64±8.6 kg).

They performed the task of blow-drying in two different ways.

The first was drying the hair horizontally (HOR), and the second was drying the hair up (UP). Figures 1 and 2 show the kinematic reconstruction of the two investigated tasks and raw signals from two of the twelve investigated muscles.

We acquired the two investigated tasks pre and after a corrective action consisting of a homemade hair dryer holder that, according to manufacturer, should reduce the shoulder elevation and abduction and the trunk and neck lateral bending.

We registered three acquisitions for the two tasks in both conditions.

For each, we acquired five cycles of drying.

We did not consider the first and the last cycles in the analysis.

The phone used was a professional one, and its weight was 850gr.

For the statistical analysis we used SPSS Statistics 17.0 software (SPSS Inc., Chicago, IL, USA).

We calculated mean and standard deviation (SD) for each electromyographic and kinematic parameter.

We considered statistically significant P-values below 0.05.

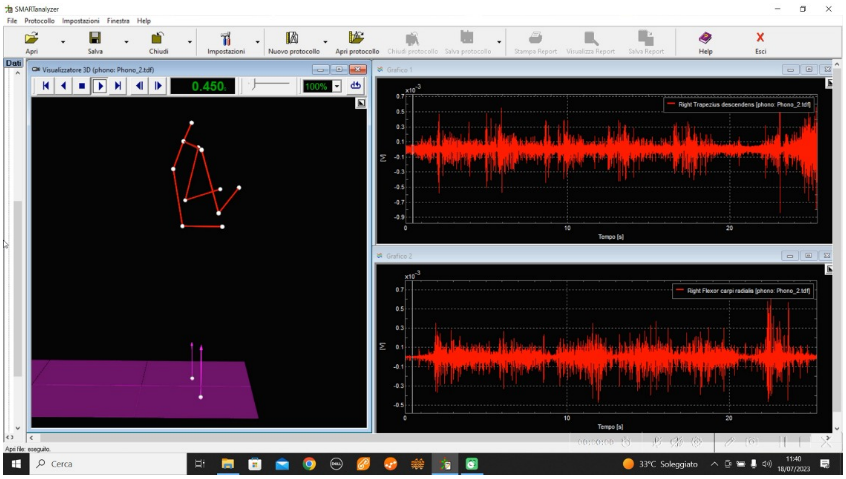

Figure 1: The image shows the 3D reconstruction of the task HOR and the raw signals from right Trapezius Superior and right Flexor Carpi Ulnaris. It is also possible to see reaction ground forces (purple arrows) from platform not investigated in this paper.

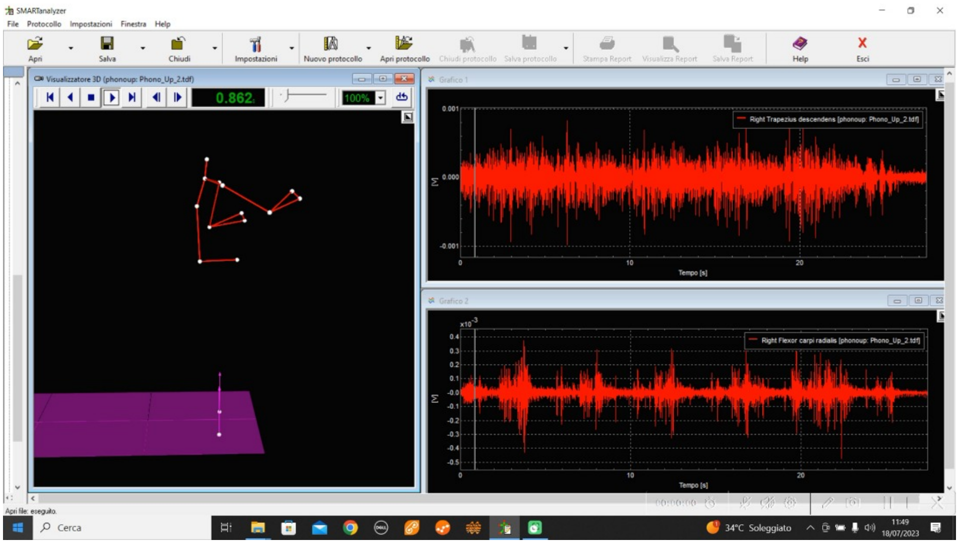

Figure 2: The image shows the 3D reconstruction of the task UP and the raw signals from right Trapezius Superior and right Flexor Carpi Ulnaris. It is also possible to see reaction ground forces (purple arrows) from platform not investigated in this paper.

Kinematic

We used an optoelectronic motion analysis system (SMART-DX System, BTS, Milan, Italy) consisting of eight infrared ray cameras operating at 120 Hz.

We placed spherical reflecting markers on the following bony landmarks: C1, C7, T10, Sacrum, right and left acromion, right and left olecranon, right and left ulnar styloid process, radial styloid process, and ASIS.

We filtered the kinematic signals with a 5Hz low bass band filter. The marker of the right elbow was used as a reference to determine the cycles (Fig.3).

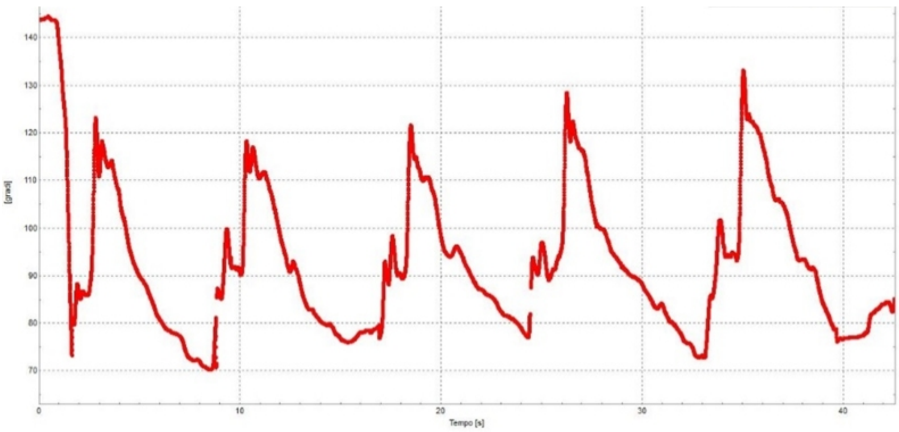

Figure 3: Image shows an example of the track from right elbow to determine the cycles.

We calculated the mean Range of Motion (RoM) of the following joint angles: neck (flex-extension, lateral bending), upper back (flex-extension, lateral bending), shoulders (abd-adduction, flex-extension, horizontal abd-adduction, elevation), elbows (flex-extension), wrists (prono-supination).

Electromyography

Electromyography was acquired bilaterally from the following muscles: Latissimuss Dorsi (LAT), Erector Spinae (ES), Trapezius Superior (TRAP), Deltoideus Anterior (DA), Extensor Carpi Ulnaris (EXT), Flexor Carpi Ulnaris (FLEX). We recorded the sEMG signals using a surface electromyography system (FreeEMG, BTS S.p.A.) equipped with 12 wireless probes at a sampling frequency of 1 kHz. We placed the probes using disposable pre-gelled electrodes Ag/AgCl (H124SG, Kendall Arabic, Donau, Germany) following the recommendations of the Atlas of Muscle Innervation Zones (Barbero, 2012). The electromyography signals were processed using Analyze software (BTS SpA, Ita). We filtered the acquired signals in the frequency band of interest [20–450 Hz] using a digital filter and Butterworth 9th-order passband to reduce motion artifacts (electrode-to-skin) and additional high-frequency noise elements. To obtain the linear envelope and extract the muscular activity profile, we rectified and filtered the signals using a Butterworth 3rd-order low-pass filter with a cut-off frequency of 10 Hz. We normalized the sEMG signals to maximum voluntary contraction (MVC). We performed MVC acquisitions according to SENIAM instructions (Hermens, 2000). Figure 4 shows an example of the processed signal of the Deltoideus anterior where, as Figure 4, it's also possible to clearly identify the five cycles of each acquisition.

We computed the mean values as percentage of Maximum Voluntary Contraction (%MVC).

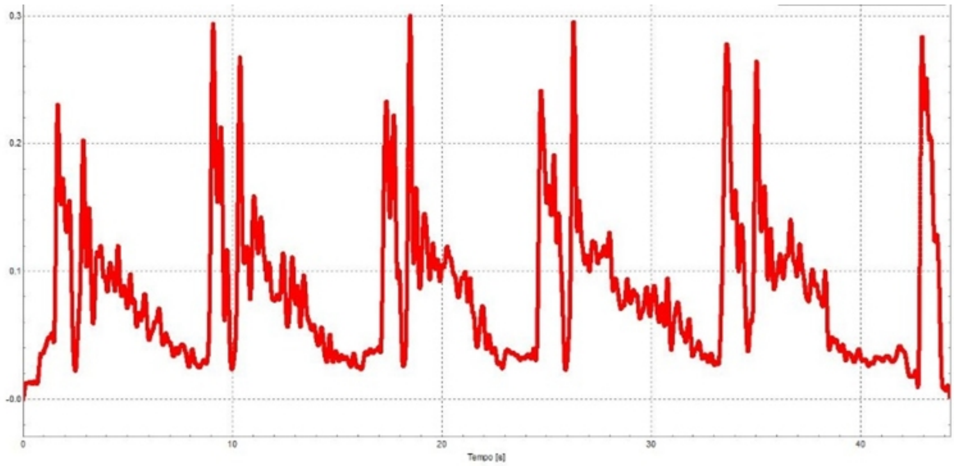

Figure 4: Image shows an example of the processed signals from Deltoideus anterior. It is possible to clearly see the five cycles of the acquisition.

RESULTS

Kinematic

Table 1 shows mean (±SD) RoMs of the investigated movements with (mod) and without the holder of the horizontal task (HOR). The last column shows the p-value.

Both neck movements showed increased RoMs when the worker had the phone holder; the flex-extension from 11.8 to 18.0° and the lateral flexion from 6.7° to 13.2°.

The back showed increased RoM values when using the holder in upper back flex-extension (6.7° Vs. 4.5°), lower back flex-extension (6.5° Vs. 3.5), and lateral flexion (4.0° Vs. 2.5).

The right shoulder showed increased RoM values when using the holder in horizontal abd-adduction (16.9 Vs. 10.5) and in the elevation (6.2° Vs. 4.8°).

The left shoulder showed increased RoM values when using the holder in horizontal abd-adduction (20.1° Vs. 14.0°), flex-extension (40.5° Vs. 31.1°), and elevation (8.8° Vs. 6.0).

Both elbow flex extension and wrist prono-supination did not show statistical differences.

Table 1. Mean RoM values (±SD), in degree, and the p-value for both the investigated movements for the horizontal task without and with the holder.

RoM (Degree)	Task HOR	Task HOR Mod	p-Value
Neck flex-extension	11.2±8.0	18.0±5.2	<0.01
Neck lateral flex	6.7±1.7	13.2±8.8	<0.01
Upper back flex-ext	4.5±2.2	6.7±4.2	<0.01
Upper back lateral flex	2.3±1.0	2.7±1.2	0.1289
Lower back flex-ext	3.5±2.9	6.5±2.0	<0.01
Lower back lateral flex	2.5±1.0	4.0±2.6	<0.01
Shoulder DX abd-add	18.2±7.9	20.5±10.9	0.3088
Shoulder DX hor. abd-add	10.5±4.6	16.9±3.9	<0.01
Shoulder DX flex-ext	29.3±17.4	34.8±16.6	0.1744
Shoulder DX elevation	4.8±1.9	6.2±1.5	<0.01
Shoulder SX abd-add	17.3±8.1	14.2±5.4	0.0601
Shoulder SX hor. abd-add	14.0±8.6	20.1±7.5	<0.01
Shoulder SX flex-ext	31.1±20.2	40.5±13.0	0.0217
Shoulder SX elevation	6.0±1.6	8.8±2.2	<0.01
Elbow DX flex-ext	22.0±8.4	25.8±14.2	0.1714
Elbow SX flex-ext	27.9±20.4	31.9±15.6	0.3532
Wrist DX prono-sup	42.1±25.4	35.0±33.2	0.3117
Wrist SX prono-sup	65.8±39.5	47.3±55.7	0.1085

Table 2 shows the mean (±SD) RoM of the investigated movements with (mod) and without the holder of the UP task. The last column shows the p-value.

Both neck movements showed increased RoMs when the worker had the phone holder; the flex-extension enhanced from 16.3 to 30.7° and the lateral flexion from 10.8° to 22.9°.

The back showed increased RoM values when using the holder for all the investigated movements. Upper back increased flex-extension from 12.3° to 18.1° and lateral flexion from 3.2° to 5.4°. Lower back increased flex-extension from 3.7° to 6.1° and lateral flexion to 2.5° to 4.8°.

The shoulders showed a statistical significance only for the abd-adduction of the right side; the RoM increased from 20.8° without the holder to 28.2° with the holder.

Both elbows showed increased flex-extension RoMs when using the holder; the right side increased from 39.0° to 63.0°, and the left side from 51.7° to 65.6°.

We did not find statistical differences for wrist prono-supination on both sides.

Table 2. Mean RoM values (±SD), in degree, and the p-value for both the investigated movements for the up task without and with the holder.

RoM (Degree)	Task UP	Task UP Mod	p-Value
Neck flex-extension	16.3±3.9	30.7±16.9	**<0.01**
Neck lateral bending	10.8±9.6	22.9±29.6	**0.0225**
Upper back flex-ext	12.3±6.6	18.1±10.8	**<0.01**
Upper back lateral flex	3.2±1.2	5.4±4.6	**<0.01**
Lower back flex-ext	3.7±1.8	6.1±3.4	**<0.01**
Lower back lateral flex	2.5±0.9	4.8±4.8	**<0.01**
Shoulder DX abd-add	20.8±18.4	28.2±12.1	**0.0476**
Shoulder DX hor. abd-add	12.0±4.0	13.7±7.4	0.2294
Shoulder DX flex-ext	49.9±25.0	59.0±30.7	0.1723
Shoulder DX elevation	9.6±4.4	11.3±3.1	0.0622
Shoulder SX abd-add	40.8±13.6	47.1±16.4	0.0804
Shoulder SX hor. abd-add	17.3±4.8	18.6±6.9	0.3566
Shoulder SX flex-ext	53.9±22.6	52.1±8.2	0.6547
Shoulder SX elevation	19.7±4.4	20.0±8.8	0.8554
Elbow DX flex-ext	39.0±36.2	63.0±32.8	**<0.01**
Elbow SX flex-ext	51.7±23.3	65.6±26.6	**0.0211**
Wrist DX prono-sup	56.0±26.9	71.3±44.7	0.0828
Wrist SX prono-sup	73.5±36.4	67.4±64.7	0.6235

ELECTROMYOGRAPHY

Table 3 shows the mean (±SD) %MVC of the investigated muscles with (mod) and without the holder of the horizontal task (HOR). The last column shows the p-value. HOR task showed statistical significance only on the left side, the side holding the comb, for EXT and FLEX. The EXT showed an increased sEMG value when using the phone holder from 17.9 to 24.1%. The FLEX showed a reduction of sEMG values from 14.0 to 9.7%. The sEMG values from LAT, ES, TRAP, DA, EXT dx, and FLEX dx were unaffected.

Table 3. Mean activity values (±SD) expressed as %MVC, and the p-value for the investigated muscle for the horizontal task without and with the holder.

%MVC	Task HOR	Task HOR Mod	p-Value
Latissimuss Dorsi DX	14.5±11.9	11.4±11.0	0.2550
Latissimuss Dorsi SX	18.3±19.7	17.6±18.8	0.8809
Erector Spinae DX	9.1±6.4	9.1±6.8	1.0000
Erector Spinae SX	9.0±5.8	8.5±4.2	0.6755
Trapezius Superior DX	8.8±7.7	8.5±6.9	0.8623
Trapezius Superior SX	16.1±8.1	14.7±3.2	0.3381
Deltoideus Anterior DX	6.9±2.3	6.1±1.6	0.0911
Deltoideus Anterior SX	12.5±7.1	11.5±7.8	0.5713
Extensor Carpi Ulnaris DX	18.9±4.5	18.1±5.0	0.4779
Extensor Carpi Ulnaris SX	17.9±9.1	24.1±13.0	0.0219
Flexor Carpi Ulnaris DX	11.3±4.8	11.7±4.8	0.7247
Flexor Carpi Ulnaris SX	14.0±4.3	9.7±2.6	<0.01

Table 4 shows the mean (±SD) %MVC of the investigated muscles with (mod) and without the holder of the UP task. The last column shows the p-value. The UP task showed statistical significance only for FLEX muscles. The right one increases the activity with the holder from 6.3 to 8.3%; the left one, which holds the comb, decreases muscle activity from 18.3 to 10.4%.

Also UP task, sEMG values of all the other muscles (LAT, ES, TRAP, DA, and EXT) were the same with and without the holder.

Table 4. Mean activity values (±SD) expressed as %MVC, and the p-value for the investigated muscle for the up task without and with the holder.

%MVC	Task UP	Task UP Mod	p-Value
Latissimuss Dorsi DX	15.2±13.2	14.7±11.3	0.8634
Latissimuss Dorsi SX	19.3±18.5	18.7±14.7	0.8793
Erector Spinae DX	16.4±15.1	14.2±13.7	0.5195
Erector Spinae SX	13.7±8.8	12.5±6.9	0.5218
Trapezius Superior DX	19.7±16.4	18.1±14.2	0.6595
Trapezius Superior SX	27.3±6.2	27.7±3.1	0.7302
Deltoideus Anterior DX	10.0±2.7	9.7±3.4	0.6797
Deltoideus Anterior SX	21.3±11.3	21.3±11.4	1.0000
Extensor Carpi Ulnaris DX	15.6±2.9	16.8±3.4	0.1116
Extensor Carpi Ulnaris SX	16.9±6.9	19.2±6.5	0.1499
Flexor Carpi Ulnaris DX	6.3±2.0	8.3±3.8	<0.01
Flexor Carpi Ulnaris SX	18.3±7.6	10.4±3.0	<0.01

DISCUSSION

Literature shows that hairdressing is a highly demanding job for musculoskeletal systems.

Hairdressers are particularly vulnerable to repetitive movements of the upper limbs, awkward and static posture. There are several tasks worthy of attention that it's hard to standardize because they depend on the type of hair that differs for every customer. The two most relevant tasks are haircut and hair-drying. We simulated this last one in our lab and acquired electromyography and kinematic signals from four experienced workers with and without an improvement proposal consisting of a homemade hairdryer holder.

Our preliminary sEMG data shows that in both investigated tasks (HOR and UP), the muscle activity of the left FLEX is lower when using the dry holder. However, the left side is those holding the comb, not the hairdryer. The right side showed increased sEMG values of the FLEX in the UP task if using the hairdryer holder.

Kinematic data shows that all the statistical significance found was against using the hairdryer holder. We found increased ROM values when using the holder in both investigated tasks for all the neck and trunk parameters but upper back lateral flexion in the HOR task.

We found significative increased ROM values of the right shoulder horizontal abd-adduction and elevation in HOR and abd-adduction in the UP task.

We also found increased ROM values when using the holder in both elbow flex-extension in the UP task.

We did no found statistical differences for wrist prono-supination in both tasks.

In conclusion, the holder seems to have more negative than positive effects on the kinematic and muscle activity of the workers. These results contrast the results of our previous paper obtained in a static analysis with commonly standardized assessment tools such as REBA. Moreover, the workers complained that the holder limited the wrist movements that should be free according to their working experience.

Limitation of the study regards the limited number of participants but as reported in EU-OSHA document (Kozak, 2019), hairdresser activity is characterized by micro enterprises. In our study it was hard to make the workers quit their work for about half a day and be acquired in our lab because workers/owners wouldn't "waste time". We plan to recruit additional workers again soon to make the statistics more meaningful. Another limitation is about the chair used that, even it was adjustable, it was not a professional one. This could affect the real movement, we tried to mitigate this bias by setting the height of the chair to the height at which the worker felt fittest.

For reducing biomechanical risk in the hairdryer task, it could be helpful to use lighter dryers like the newer ones that allows to hold them in a correct posture and avoid homemade solutions like the holder texted in this paper. Training is also a key particularly in the early phases of education in hairdressing to prevent workers learning wrong postural behaviors. Another point for reducing biomechanical load in hairdresser is to increase the breaks. However, this is not often possible because it leads to smaller earnings and it depends by the customer affluence that fluctuates day to day. Receiving customers for appointments could result in a better organization of the activity avoiding busy days and, thus, decrease the workload.

Finally, we recommend applying instrumental-based tools (CEN, 2023) for a more reliable biomechanical risk assessment in hairdryers because common standardized protocols, used in previous papers, are not able to describe the hairdresser activity that, according to our data, is not as simple as it seems.

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