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The impact of work clothing design on workers' comfort

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Abstract

Physical and physiological comfort, at work and during leisure time, is important to human health and motivation. A growing number of jobs require workers to sit. Most clothes, except those intended for wheelchair users, were designed for walking or the standing position. Clothing designs should be user-oriented and meet users' needs. Garment design should conform to body position and posture, not just shape and size. In this paper we present the ergometric impact of a new type of trousers designed to adapt to changes in position. Concentrations of compression forces, temperature and pressure were documented in an exploratory pilot study and contrasted to traditional designs. The new trousers showed significant decreases in compression force concentration, especially in and around the knees and waist. Most participants identified comfort as an important factor when purchasing a pair of trousers and that, for working purposes, they would prefer these special trousers rather than traditional designs.

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Keywords: Sitting position; Clothing design; Comfort; Compression; Pressure.

1. Introduction

People are increasingly sedentary, especially at work, where they may spend 8 to 9h with minimal mobility [1]. Most working adults spend 1/2 to 2/3 of their time at work in a sitting position [2], and in some jobs, such as the case of call centers, the time spent on sedentary behavior can reach 90% [3].

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Sedentary behavior is an independent risk factor for obesity, diabetes and some types of cancer [4, 5]. Prolonged sitting has been associated with swelling of the lower extremities, discomfort, venous disorders, and vascular derangements [6, 7, 8]. Sitting may be less stressful on the lower extremity joints [9, 10], but at the cost of increased risk of low back pain [11, 12]. Many health specialists, such as orthopedists and physical therapists, assume that the de-conditioning of the trunk and lumbar spine structures occur with long-term sitting without longer active periods of standing, walking or running, causing low back pain and accelerated degeneration of lumbar spinal structures [13].

Apart from the adverse health effects caused by the sitting position, the body's shape and size also changes. Carvalho et al. [14] performed a comparative anatomical study between the standing and sitting positions, analyzing the dimensional and postural alterations of the individuals. With this information they identified the changes that occur when people sit, including:

- Shortage of the trunk;
- Increase in volume in the abdominal region;
- Change in height, volume and inclination of the waist;
- Enlargement of the hips;
- Redistribution of the muscular mass in the thighs;
- Increase of upper-back bending;
- Modification of the angular position of the elbow;
- Increase of the leg frontal length caused by the flexion of the knees.

Wearing appropriate clothing can attenuate at least some of these changes, thereby preventing health issues and increasing perceived comfort. Physiological comfort can be defined as a physical sensation of well-being. It is more than the absence of physical distress, since it denotes an agreeable experience associated with a feeling of contentment and satisfaction. Comfort can be influenced by intrinsic (e.g. physical characteristics of the fibers and materials) and extrinsic factors (e.g. brand labels, price) related to the garment itself or related to the wearer (e.g. expected comfort and satisfaction) [15]. Two of the most important factors that influence the perception of comfort are the ability of the clothing to handle thermal and pressure concentrations. The thermo-physiological comfort of any garment is defined by those intrinsic characteristics such as thickness, air permeability, and water vapor permeability. The presence of seams in areas that come into contact with any objects, for example, have a significant impact in user perception of comfort.

There is a great gap in the fashion industry that fails to provide garments adapted to the positional constraints of different tasks, especially when users are seated. Most clothing is designed for people who are walking or standing, and indeed fitting is performed while erect. However, the number of jobs requiring a sitting position is continuously increasing, and market-available garments do not take this into account. As previously mentioned, when we sit, the shape and size of most body parts change, making the user uncomfortable. In the case of trousers this problem is more evident. The existence of overlapping fabric, thick seams, and accessories create or exacerbate high pressure points on the body. The foci of humidity, pressure and subsequent local deprivation of oxygenation and blood circulation in these areas while sitting in such clothing for long periods of time can result in great discomfort and worse, even damage.

Several aspects that should be taken in consideration when designing garments for the seated position are accommodations that account for: (i) the increase of trouser body rise in the back and decrease in the front; (ii) the accumulation of excess fabric in the abdominal area and exposure of the back area; (iii) variation in leg length; (iv) presence of thick and hard seams in areas exposed to high pressure such as back and buttock areas.

The only available trousers that are more appropriate for the sitting than standing position are designed for wheelchair users. However, these designs are not often comfortable or aesthetically pleasing. Recently, researchers developed a pair of jeans designed to accommodate postural changes – the FYT jeans. Most people, during their daily routines, have moments of motion and moments when they are sedentary, so that the most important issue is to ensure that the trousers they are wearing are comfortable and suitable for every occasion. Apart from their intrinsic textile properties, several features were added or altered in a way that is intended to increase the users' thermo-physiological comfort and, consequently, their performance at work. Most importantly, the jeans' design is intended to allow for long periods of use while seating down, keeping in mind the ergonomics of this position, which differs largely from the ergonomics of a human body standing. These revolutionary jeans have the following principle characteristics:

- Reduction of pressure points on contact surfaces;
- Possibility of waistband growth in accordance with the demand of changing waist dimensions with changes in posture. This allows a reduction in pressure forces in the region where the trousers grip the waist;
- Possibility of opening an invisible zipper in the sacral area when the user sits, allowing for the growth of the crotch length (with inner tissue). This allows a reduction of the compression forces by repositioning the trouser waistband, providing higher levels of comfort;
- Removal of excess tissue accumulated on the back of the knee when the user assumes the sitting position.

This paper presents a pilot exploratory study of workers' perception of regular jeans, designed for the standing position, and FYT jeans specially designed for dynamic and sitting positions.

2. Methods

2.1. Data collection

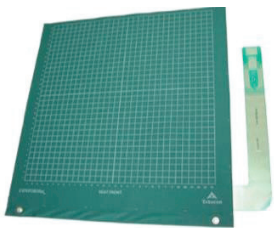
Six subjects participated in this pilot test. Since an important aspect of this study was the perceived comfort reported by the users in the sitting position, the selected participants were limited to people that work in the seated position and that usually wear trousers similar to those tested in this study.

In this test, variables related to compression, temperature and pressure were analyzed, using appropriate sensors (Figure 1).

Compression was measured with six Plux© compression sensors (Figure 1a). These sensors were physically connected to a device, which then transmitted recorded data via Bluetooth to a tablet. The same device supported one temperature sensor (NTC thermistor) that was attached to the back of the participant's right knee (Figure 1b). Pressure was measured using a Tekscan's ConformatTM #5330 (Figure 1c) and Research software. This mat is composed by 1024 piezoresistive organized in a 32x32 square array. The compression sensors and the temperature sensor were placed with adhesive tape on several body locations, (Figure 2). The mat was placed on a typical office chair where participants sat and worked as usual, thus enabling the recording of the contact pressure between the seat and the participant.

a) Compression sensor

b) Temperature sensor



c) Pressure mat

Fig. 1. Sensors used in this study.

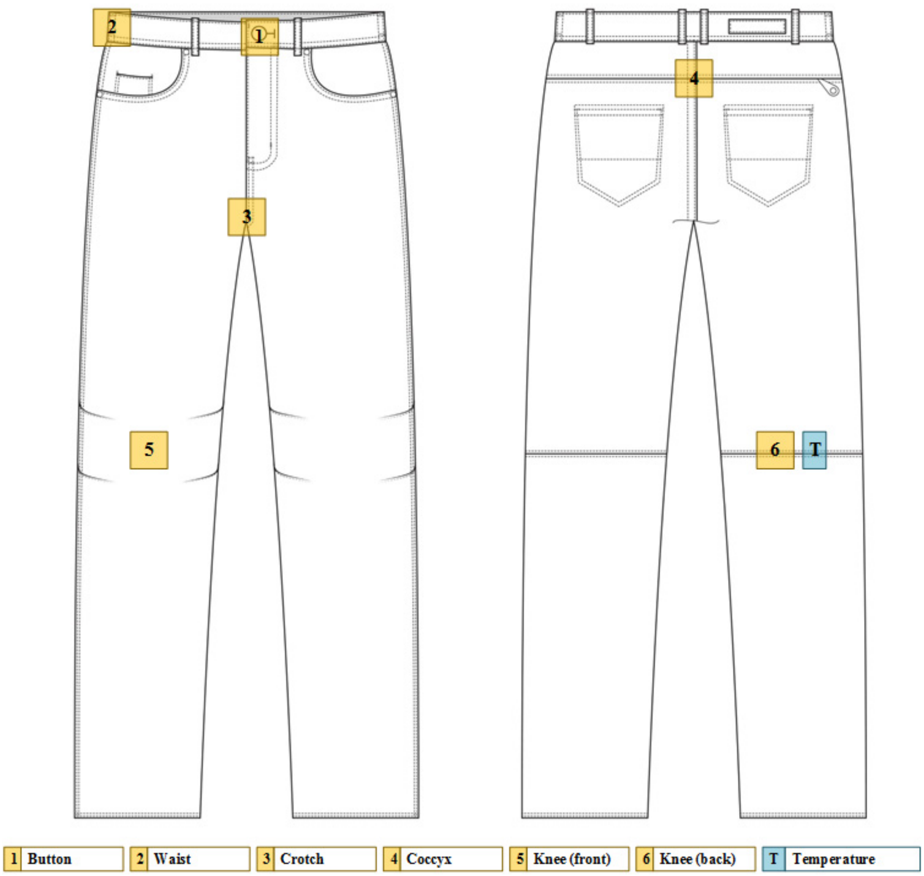


Fig. 2. Location of the sensors in FYT jeans patented design.

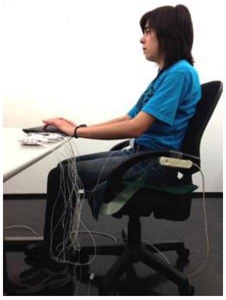
The test was performed for all six participants at the beginning of the day, to ensure that they all would be able to wear the trousers for a whole working day (approximately an 8h period).

The measurement procedure consisted of three different stages:

1. Measurement with regular jeans;
2. Measurement with FYT jeans (sacral zipper closed);
3. Measurement with FYT jeans (sacral zipper open).

Each measurement was conducted for 15 minutes, for a total of 45 minutes. During these 15-minute measurements the participants were asked to perform their usual tasks, sitting at a desk, in front of their computer (Figure 3). The first measurements were conducted with participants wearing their personal jeans, while the second and third set of measurements were conducted with participants wearing the FYT jeans provided for this study. To ensure that the data were comparable the size and shape of the two trousers were similar. In the first two measurements all the participants wore the same belt adjusted for appropriate dimensions. In the second set of measurements the sacral zipper was closed and open in the third.

At the end of each measurement the participants had to stop working for one or two minutes to enable readjustment parameters and calibration of sensors, including changing from the regular jeans to the FYT jeans between the first two stages and removal of the belt and opening of the back zipper between the later two measurement stages.



a

b

Fig. 3. Measurement process. a. Participant performing usual tasks; b. Detail of the sensors' position.

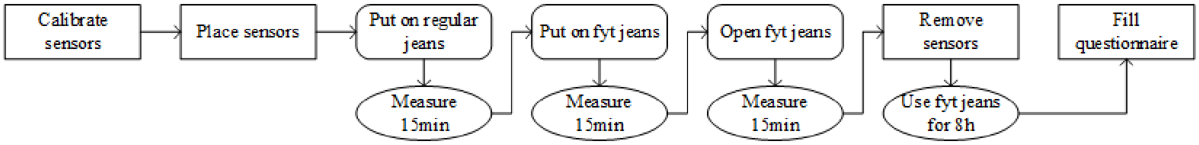


Fig. 4. Summary of the data collection process.

Before starting the measurement process all sensors were calibrated. After that, the small compression sensors and the temperature sensor were placed on the predetermined body sites (Figure 2).

After all the necessary data were collected participants were asked to continue working and performing their usual workplace tasks in FYT jeans. At the end of the day, each participant had to return the trousers and complete a short Likert-type scale questionnaire designed to evaluate participants' perception of comfort and work performance. Different gradations of comfort and performance were included, including overall perception of physical and thermal comfort, performance at work, range of motion allowed, and the impact of these jeans on self-image. Moreover, several body areas were identified and specific questions were asked as to the level of thermo-physiological comfort at each area, as well as on the presence or absence of physical signs of irritation, such as redness on the skin. Finally, 20 features that can influence a customer's decision when buying jeans were identified. The participants were asked to order these features from the most important to the least important.

Figure 4 summarizes the procedure used in this pilot study for data collection.

2.2. Data analysis

For the compression and temperature sensors, three observations were recorded every five minutes for each measurement, totaling nine records for each participant. The mean of these three observations was calculated, as was the variation that occurred between measurements. These comparisons were analyzed in terms of decrease (in percentage) of the compression in the various body locations.

Data from the pressure sensing mat was analyzed with Tekscan's® Research software and with a custom-made LabView application. One of the variables selected was peak pressure over time, where the software displays the peak pressure achieved in each sensor location during the entire trial, and then tracks the four sensor locations with the most pressure over time. Within this variable it is possible to determine several parameters, such as mean pressure, minimum and maximum pressure values. All these possible analysis were undertaken with the objective of determining whether there were any differences in pressure between participants' regular jeans and the FYT jeans.

3. Results and discussion

Table 1 shows the sensors that recorded the largest reduction in compression for each participant for each of the three trouser configurations. As can be seen, in the first comparison between traditional and FYT trousers, for most participants, the most significant improvements occurred in the knee area (sensor 5. Knee (front) and sensor 6. Knee (back)). The largest reduction in compression force was 77,39% for the back region of the knee, and 65,08% for the front of the knee. The sensor placed on the crotch (sensor 3. Crotch) also showed significant improvements, with a maximum of 55,31% lower compression. In the second comparison, between closed and open sacral zipper configurations, the waist region showed the most significant improvements, with a maximum value of 89,06%. The coccyx area also showed some improvements, up to almost 50%. The last comparison, between regular jeans and the FYT jeans with all their features, indicated that the highest difference was in the waist area (sensor 4. Waist), with over 90% of improvement. Some high levels of decreased compression were also found for the knee and coccyx areas.

Table 1. Decrease in the means between measurement 1 and 2 for each participant.

Participant ID	Between 1 and 2 (%)	Sensor	Between 2 and 3 (%)	Sensor	Between 1 and 3 (%)	Sensor
P1	65,08	5. Knee (front)	45,88	4. Coccyx	78,90	4. Coccyx
P2	58,53	5. Knee (front)	89,06	2. Waist	90,67	2. Waist
P3	11,71	3. Crotch	1,28	3. Crotch	12,84	3. Crotch
P4	77,39	6. Knee (back)	28,85	5. Knee (back)	83,91	6. Knee (back)
P5	33,41	5. Knee (front)	59,96	2. Waist	64,08	2. Waist
P6	55,21	3. Crotch	49,12	2. Waist	61,38	3. Crotch

Figure 5 shows the highest decrease in compression values for each sensor for each comparison. Compression fell in the waist and buttocks areas even with the FYT jeans worn with a belt and the back invisible zipper closed and even further with the zipper opened. A slight improvement in temperature concentration (~10%) was achieved as well. The knee, when sitting, is an area that tends to be hotter than the rest of the legs. FYT jeans are cooler than the regular jeans and allow better air circulation in the back of the knee.

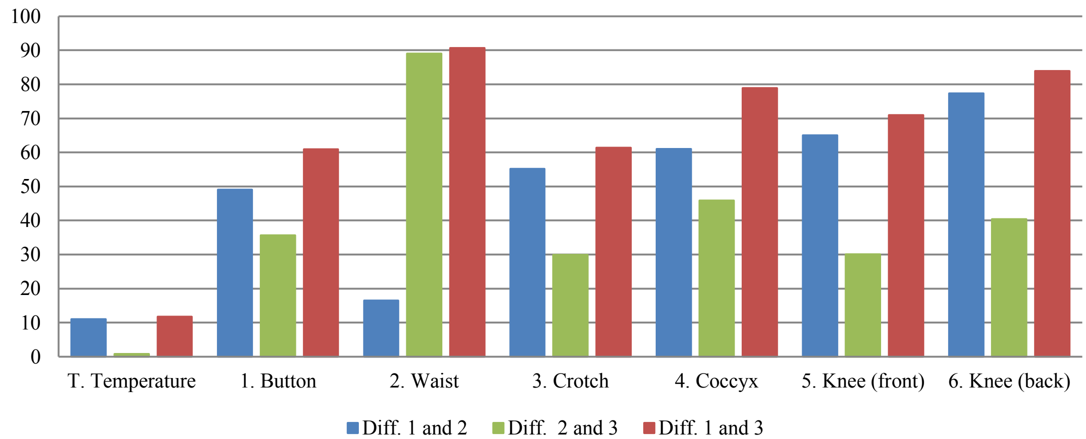
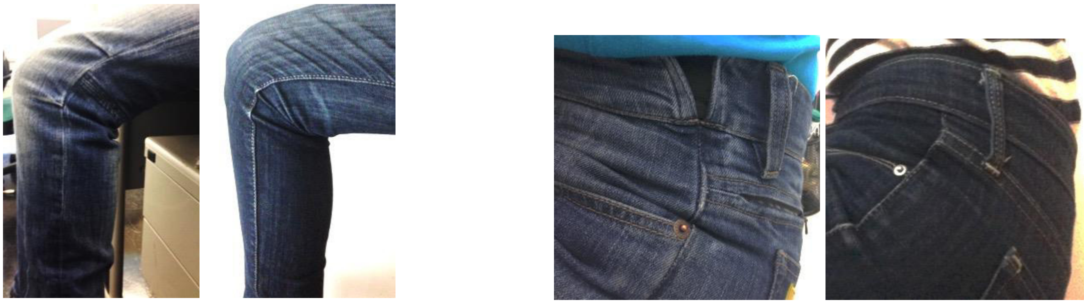


Fig. 5. Decrease in the means between measurements for each sensor.

In comparing FYT and regular trousers, the highest difference was found in the knee, testifying to the relevance of the design alteration in the knee area. The way the fabrics surrounding the knee are designed allows for greater range of motion and higher comfort levels. In most regular jeans there is excessive fabric on the back of the knee causing some discomfort. This discomfort, caused by the high compression of the jeans, may lead to marks on the skin, itchiness or redness. Figure 6 a) shows the difference between regular jeans (right in the picture) and the FYT jeans (left in the picture) in terms of excessive fabric in the knee area. The small elastic in the waistband came into play when the zipper was open and allowed for more space for the body and more freedom of movements.



a b

Fig. 6. Details of FYT jeans features. a. Knee; b. Waist.

After analyzing all pressure data obtained from the pressure mat, it was found that there were no significant differences in pressure or center of force trajectory between jeans. This was to be expected, since the FYT jeans tested in this study are not meant to reduce pressure in the buttocks, which was the only area covered by the sensing mat. These jeans maintain roughly the same seams and back pockets typical of most jeans, thereby making any significant decrease in pressure unlikely. However, there is a second type of FYT jeans available, where the back pockets are interior and do not go under the buttocks area. In this case, it is expected that the values of pressure recorded will be significantly different. Further studies will be conducted with these jeans in order to evaluate pressure reduction in the buttocks.

Five of the six participants graded FYT jeans as more comfortable than their usual jeans. The FYT jeans had no apparent influence on participants' performance at work. As for range of motion, all participants but one assessed these jeans as allowing for more freedom of movements. The jeans had no influence on participants' self-image.

As for the thermo-physiological comfort at specific body sites, half of the sample mentioned a slight decrease in comfort in several areas, such as the waist and crotch. Further inquiries suggest that this was caused by the fact that these jeans are high-waist, whereas these participants' usual jeans are low-rise. Future studies must take this into account and match the FYT jeans waist type with participants' usual jeans. However, it is important to note that all but one mentioned higher levels of comfort for the FYT jeans in several areas, most importantly at the knee level, both front and back. This data confirms the results obtained with the compression sensors. Perceived pressure exerted by the jeans was evaluated mostly as less than the usual, with the exception of the same participants that wear low-rise jeans, who mentioned a higher perceived pressure in the crotch and waist.

Finally, all participants named comfort in their top five features when buying jeans, with four of them naming comfort as number one. Interestingly, the feature of being appropriate jeans for work was included in all participants' top 10 features list.

4. Conclusions

Comfort is an important aspect of body image – especially at work – and clothing is central to the perception of comfort. Yet, though the majority of people spend the greatest part of their day in the sitting position, clothing fit is most often determined while erect and rarely accounts for changes in posture. Clothes in general and trousers in particular are designed for the standing position, causing discomfort or even pain in some areas of the body when the seated position is assumed.

We compared a new pair of jeans (FYT) designed to accommodate postural changes to traditional regular jeans in terms of compression, temperature and pressure. A brief questionnaire graded participant perceptions. The FYT jeans created less compression especially for the knee, crotch and waist areas and increased thermo-physiological comfort. Given the exploratory nature of this study, these results encourage further investigation in this area.

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