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Towards Reducing Musculoskeletal Disorders Among Local Fashion Designers in South-Western Nigeria

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Abstract

Local fashion designers (FaDes) are faced with the daunting task of sewing clothes. Sitting position, a reflection of the type of chair used, is one factor influencing their performance. This study evaluated the currently used FaDes chair and the effect of sitting posture. It also designed and fabricated an improved fashion designer (IFaDes) chair. Assessment of the ergonomic status of the FaDes chair was carried out and anthropometric data were obtained using a structured questionnaire among 375 apprentices and 125 managers. Percentile distributions of data were analyzed using statistical package for the social sciences. The survey yielded 88% response rate of which the majority reported to have experienced various difficulties with the FaDes chairs. Neck, leg, hand, waist and back pains were commonly reported with waist pain as the most prevalent (75.5%). The anthropometric data with the percentiles (5^{th}-90^{th}) were popliteal (36.30-53.00 cm) and buttock height (14.95-33.00 cm), seat (22.00-33.00 cm) and buttock breadth (19.00-30.00 cm), and buttock-popliteal length (35.00-49.49 cm), among others. Using these data, the IFaDes chair's design was conceptualized through Solidworks; it was then fabricated using locally available materials. The provision of backrest to supports user's torso was an added feature. Qualitative evaluation of the IFaDes chair was employed using the same respondents for a minimum of 168 h. The respondents reported that the IFaDes chair was satisfactorily designed and fabricated. They experienced improved comforts in sitting posture and reduced musculoskeletal disorders.

***Keywords**:* chair design, ergonomics, musculoskeletal disorder, fashion designers, improved chair

1. Introduction

Fashion designers (FaDes) spend most of their time per day sewing fabrics and other materials. Local FaDes sit on anything they presume to be more comfortable from stools, bench and buckets, among others. The continuous changing of different sitting positions occur due to sitting disorders and prolonged body pains. Verbal inquiries have shown that FaDes experience an extreme pain in the process of satisfying customer's design needs; thus, leading to delay and low-quality work. The chair affects their sitting posture. It is the human nature to adopt; hence, FaDes tend to sit with their back bent irrespective of the type of chair.

Anthropometry and ergonomics have been utilized to create undertaking or office work areas and seats by consolidating movability to suit a more extensive scope of individuals and population. Even though flexibility has been an essential model in numerous plans by the mid-1960s (Kelly, 2005), the estimation of customizable plans has become a subject for discussion in situations where there are multiple measurements to modify and experienced issues in figuring out what fits best. The point of convergence of the ergonomic structure of chairs has been largely established on the arrangement of working chair, subject to the anthropometry and biomechanics of the human body. This, among many other reasons, necessitated the need to carry out this study aiming at achieving the best-suited chairs for FaDes. According to Jin *et al.* (2004), there is a high occurrence of discomfort in the fashion industry potentially due to workers who perform their tasks in forward-leaning positions causing low back and other related pains in the body regions.

The fundamental logic of ergonomics is to make any plan leading to ease, physical well-being, safety, prosperity and bringing thought process towards work completion. The ergonomic design of the FaDes chair is aimed at providing full comfort for FaDes. Ergonomics is defined as the investigation of the structure of a workplace, equipment, machine, tool, product, environment, and framework, which mull over individual's physical, physiological, biomechanical, and mental abilities; and streamline the adequacy and profitability of work frameworks while guaranteeing the safety, well-being, and prosperity of the workers (Fernandez and Goodman, 2011).

Ergonomics design has antecedents in proper assessment of users' anthropometry composition. Anthropometry is the gathering of elements of the human body and proportions (body length, width, circumference, and skinfold thickness). It is helpful in attire measurement, criminology, anthropometry and ergonomic plan of the work environment (Wang *et al.*, 2000; Ismaila *et al.*, 2015). Similarly, some authors defined anthropometry as the method used in ergonomics to specify the physical dimensions of workplace, equipment, furniture and clothing (Chou and Hsiao 2005; Davis *et al.*, 2009). The real components of the user population are significant in the structure of workstations to suit sound and comfortable posture. Confounding human anthropometric and equipment measurements might be contributing components leading to accident rates and medical issues, namely musculoskeletal disorder, strains and total injuries.

A fashion designer who always has to bend his or her back in doing his or her work has a very high potential of getting physically deformed body shape that could take years to correct and some cases even become permanent. According to Choobineh (2004), improper chair design affects weavers' capacities and causes spinal pain. Poor postures are frequently prompted by inadequately designed seat, work table and unfriendly environment. FaDes sometimes adopt backward position leaning against their machine or placing their hands back on the table to support their body. This awkward posture could be a result of badly developed seat. A suitable design for FaDes chair can enhance safety, comfort, health and effective performance.

The FaDes' workshop floor tends to wear out due to continuous dragging and adjusting of the FaDes chair and the machine table while trying to achieve a comfortable position as shown in Figure 1.

Figure 1. A local fashion designer workstation

The fashion designer places the chair close to the door or wall to have a resting position. The placement of this machine in awkward positions also disrupts the movement of workers in the FaDes' workshop floor.

1.1 Ergonomics and Anthropometrics Relevant to the Current Work

Ebben (2003) underscored that sitting is preferred over standing as a working position. The static, low dimension movement of the soleus and tibia in foremost muscles is required in standing and these muscles become weak in the end (Morrison, 2018) because drainage of the lower limbs may occur if a person stands still for a long period of time (Juan, 2017). Venous return depends on the pumping action which occurs only during rhythmic contraction of the leg muscles that happens when an individual moves or during postural sway (Wieling *et al*., 2014). Venous pooling in the lower limbs causes swelling at the lower legs. In extraordinary conditions, the diminished progression of blood back to the heart may cause a drop in circulatory strain causing an individual to black out (Gorman *et al.*, 2001). The hydrostatic head, which must be defeated to return blood to the ears from the lower appendages, is less in sitting than in standing if the seat is accurately designed (U.S. Navy Diving Manual, n.d.).

According to the Canadian Centre for Occupational Health and Safety (2020), a well-designed ergonomic chair is a jump-off in solving many associated problems in trades involving prolonged sitting – chair is one of the major components to be considered in workstation design. However, studies on the design of ergonomic chair for FaDes are very uncommon. Gopura and Amarasena (2008) designed an ergonomically efficient chair for the long time seated workers to enhance comforts at work. Ergonomic chairs were also designed with the aim to satisfy all the basic needs of students in primary schools and tertiary institutions (Oyewole *et al*., 2010; Ismaila *et al*., 2013, 2015; Taifa and Desai, 2017) and in classroom environment (Al-Hinai *et al*., 2018). Festervoll (1994) had worked on the development of ergonomic chairs and seats for transportation, industry, banks and offices while Noshin *et al.* (2018) made an attempt to design an ergonomically fitted office chair to improve users' productivity. Vandyck *et al.* (2013) reported biomechanics of sitting posture and anthropometric measurements for seated workers in garment production and concluded that the chair used by workers were an important risk factor contributing to muscle pain and injury. The authors, however, called for a proper redesign of the chair.

Age, sex, race, land areas and even unique occupations affect human body measurements. According to Avinash *et al*. (2014), the general issues experienced in seats uncoordinated with the body are shown in Figure 2. To address these issues, anthropometric measurements are examined for various percentile and reasonable anthropometric measurements are chosen for the multi-utility seat as product particular. The product particulars are resolved through the point-by-point investigation of static anthropometric information of human body in seating position like buttock to popliteal length (Figure 3a), height of popliteal from ground (Figure 3b), elbow height from sitting surface (Figure 3c), free leg room (Figure 4a), and curvatures of sitting surface (Figure 4b). Figures 2 to 4 are originally from Avinash *et al.* (2014).

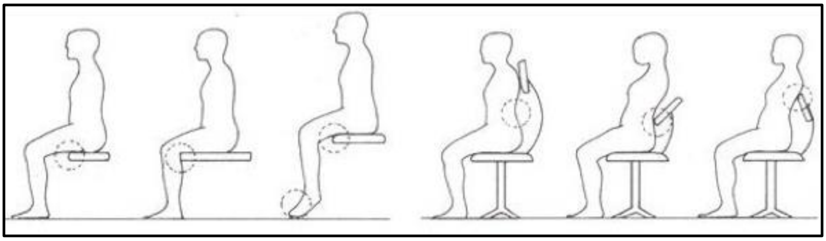

Figure 2. Discomfort due to mismatch of human body and seating positions

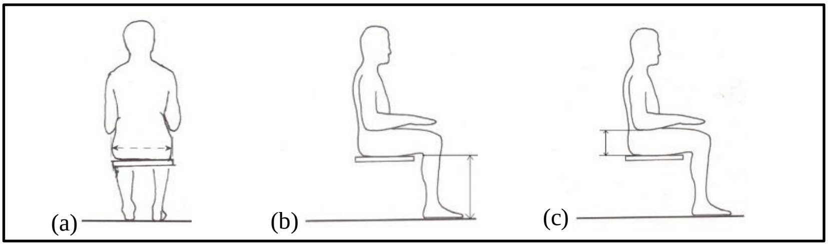

Figure 3. Seat breadth (a), height of popliteal from ground (b) and elbow height from sitting surface (c)

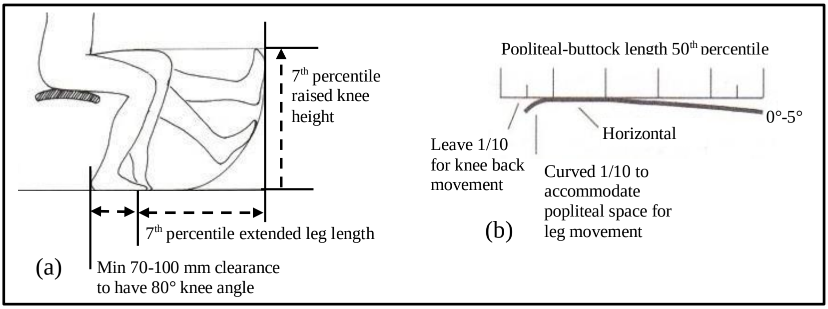

Figure 4. Free leg room (a) and curvatures of sitting surface (b)

1.2 Characteristics of Ergonomic Chairs

Some of the ergonomics issues among work station chairs necessitating redesign, as mentioned by some related studies (Gopura and Amarasena, 2008; Oyewole et al., 2010; Vandyck *et al.*, 2013; Ismaila *et al*., 2015; Taifa and Desai, 2017; Al-Hinai *et al*., 2018), include wrong height, lack of back support, uncomfortable sitting surface and lack of adjustable armrests. As highlighted by MacLeod (2008), George *et al.* (2014) and the Occupational Safety and Health Administration (2018), some of the qualities of ergonomic chairs include height, depth, and backrest edge adjustability, chair reclines or tilts, pan edge adjustability, armrests, height adjustable armrest, width-adjustable armrest, and backrest height adjustability.

Height adjustability enables the users to alter the seat with the goal that his/her feet are on the floor, or the sewing machine pedal is at a proper stature, or ideally both.

Depth adjustability is accomplished either by backrest in-out customizability or a sliding seat dish; this changes the front-to-back profundity of the seat. A shorter seat dish enables short individuals to utilize the seat's backrest while a more profound one feels increasingly stable for tall people.

Backrest edge adjustability changes the point of the backrest concerning the edge of the seat. Backrest edge customizability enables the seat to help distinctive degrees of lean back, which exchanges some chest area weight to the seat backrest, and relieves the burden on the lower back's intervertebral discs.

Chair reclines or tilts change the point of the whole seat concerning the floor. Similar with backrest point customizability, a leaned back seat exchanges some chest area weight to the backrest of the seat.

Pan edge adjustability changes the forward-back point of the seat. The principle motivation behind forward tilt is to open the point between the trunk and thighs, actuating lordosis and lessening disc weight.

Armrests help the arms by releasing the loads from shoulders and upper arms. Height-adjustable armrest prevents issues on extremely high armrests, which result in raised shoulders and weight on the undersides of the elbows and lower arms, and very low armrests that require a worker to droop or shelter one side to utilize them. Width-adjustable armrests, a sort of adjustability, changes the separation between armrests. Armrests that are near the body can help maintain a strategic distance from spread elbows, thereby causing the wrists to twist to the side amid exercises – keying for instance.

Backrest height adjustability alludes to an adjustment in tallness of the lumbar help territory of the seat backrest. This element obliges inclinations by various laborers as to where and how the lumbar help bend contacts the back.

As evidenced by previous studies showing the effects of musculoskeletal disorders on individuals who constantly use non-ergonomic chairs, there is a need to develop an ergonomic chair for FaDes. Hence, this study was carried out to evaluate the currently used chair, and redesign and fabricate a new one using ergonomic and anthropometric parameters to improve FaDes' sitting comfort and health, thereby eliminating musculoskeletal disorders.

2. Methodology

2.1 Conduct of Ethical Issues during Data Collection

To reduce the level of biases in data collection, indirect questions were included. Open-ended questions were added to allow for participants' expression of views on information not provided in the structured questionnaire. The development process of the questionnaire was reviewed by three ergonomics professionals from academic field. Participants were encouraged to go through their provided answers to be sure that their answers were the true picture of their mind before final submission. The proposed process involving human participants was reviewed by research ethics committee in the Faculty of Engineering of the authors' institution. This step was taken to protect the potential participants in the research. It also considered the potential merits and demerits and the possible risks for the workplaces wherein the study was carried out.

Constructive advice was also obtained before the commencement of the study. The ethical approval containing a set of instructions on how to ensure safety (for both researchers and participants) was received from the ethical committee in the work domain of the authors. The reasons for the study were fully communicated to all the participants so that they can voluntarily decide whether to participate or not. Consents were taken in oral form from all participants after they were informed that their participation in the study was voluntary.

2.2 Study Area and Data Collection

The study areas covered were within Ogun and Lagos, Nigeria. These areas were selected because fashion designing job is common and for ease of accessibility of the researchers to the participants. The study included 500 respondents comprising 375 apprentices representing 75% of the total participants and 125 managers (25%). The collection of data was done through questionnaire, individual interviews, direct anthropometric measurement, observation and reports from experts in the ergonomics field. The questionnaires were administered to the FaDes with at least two years of work experience and those with long years of exposure to the job. The apprentices were people who were learning how to sew clothes during the conduct of the study while the managers were the apprentices' instructors and/or the owners of the fashion shop.

2.3 Collection of Anthropometric Parameters

The anthropometric data of 251 participants were successfully measured quantitatively. This included 77 (61.6%) of the managers and 174 (46.4%) of the apprentices. These subjects were randomly selected among those who agreed to participate in the process. The parameters measured included popliteal and knee height, buttock popliteal and buttock knee length, seat and buttock breadth, buttock height and forearm length. The tools used for data collection were 150 cm calibrated tape measure made of latex material, and 120 kg capacity flat surface weighing scale.

2.4 Determination of 5th, 50th and 90th Percentiles

Anthropometric measurements for populace are positioned by size and depicted as percentiles. A percentile estimation of an anthropometric measurement speaks to the level of the populace with a body measurement of a specific size for configuration purposes.

The data collected on the anthropometric measurements from 251 participants were analyzed with statistical package for the social sciences (SPSS) software using nonparametric equivalents of the between-subjects *t*-test – the Mann-Whitney U test. This test helped in deciding whether the middle of a variable for members in a single gathering is altogether or not slightly the same as the middle of the variable for members in an alternate gathering.

2.5 Development of the Improved Fashion Designer (IFaDes) Chair

The design was laid out on SolidWorks software (2018 version) where the necessary engineering drawings were obtained and a subsequent prototype was developed using three-dimensional printer to show a clear representation. The self-weight of members were estimated and the critical (worst combinations) loading was also determined (dead loads alone, and dead and imposed loads combined) and analyzed the framework to find forces from all members. The imposed load in this case was the average weight (63 kg) of the participants obtained from the anthropometric data. According to Chegg (2008), the minimum amount of the stress, exerted by the external force acting over the body that is required in initiating the motion towards causing failure, is known as critical stress. Hence, for the material and section to produce in each member, a stress value not exceeding the critical value was selected. The fabrication process was carried out thereafter in the mechanical workshop of the corresponding author's institution.

3. Results and Discussion

3.1 Reported Conditions of the FaDes Chair

A total of 440 copies of the questionnaire were recovered representing 88% study survey response rate. When asked to comment on the currently used chair for the job, respondents' level of acceptance was very low (Figure 5). Less than 40% of the respondents were generally comfortable using the chair; less than 20% of them were able to cope with using chair without torso support. Data also showed that 30% of the respondents were comfortable with the height of the chair; 13.5% felt secured working with backless chair; 35.8% agreed with the current curvatures of the sitting chair; and about 20% considered the material that made up the chair as good for their job.

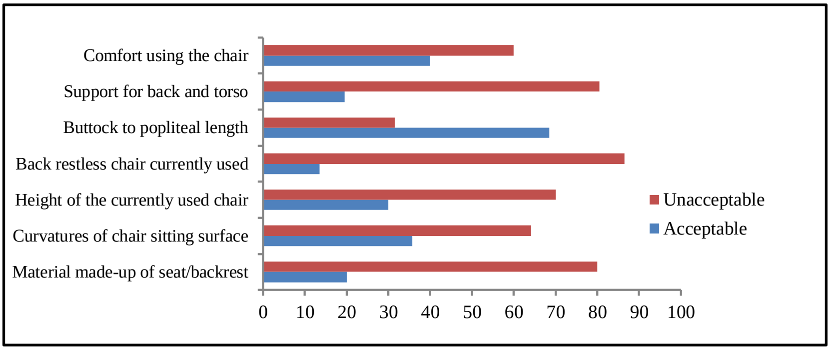

Figure 5. Respondents' level of acceptance of the FaDes chair

3.2 Response to Work Related Pains

A total of 370 (84%) participants reported pains lasting 24 h in the last 12 months. In Figure 6, it is shown that 98.9, 74.6, 72.8, 63.5, and 58.6% complained pains in the leg, lower back, waist, upper back, and buttock, respectively. Others included neck (30%) and hand/finger pain (6.8%).

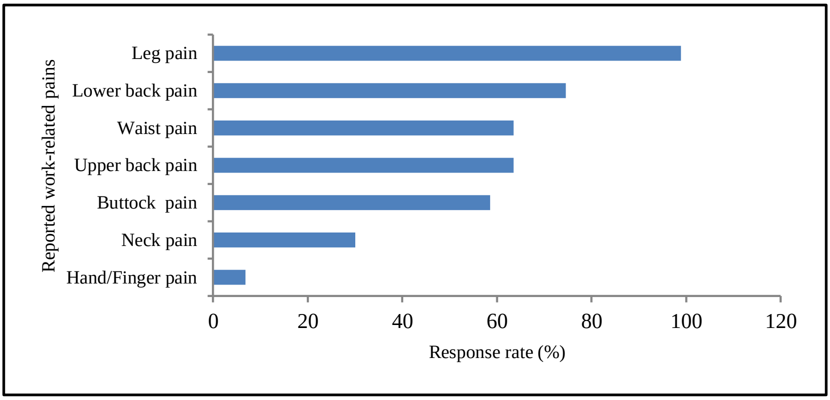

Figure 6. Reported work-related body pain

3.3 Respondents' Opinions on Developing an Improved Chair

There was a closely related opinion between those who believed that a comfortable chair can improve the quality of job performance. As indicated in Figure 7, 52% of them were certain of possible improvement in their efficiencies if provided with better comfortable chair; however, 44% disagreed with this view. Furthermore, 91.8% opined that they need another comfortable chair to ease their work; almost the same number of respondents (88.8%) reported that adjustment is needed with the currently used one if possible.

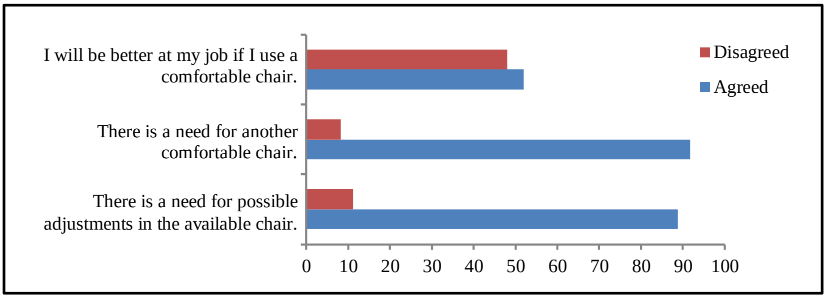

Figure 7. Respondents' opinions on having an IFaDes chair

3.4 Chair's Areas Requiring Adjustments

As shown in Figure 8, respondents cited that they need a better designed chair to improve comfort in their buttock (92%), upper back (65%) and lower back (90%) regions. A total of 78% respondents wanted an improved chair that can reduce leg pain.

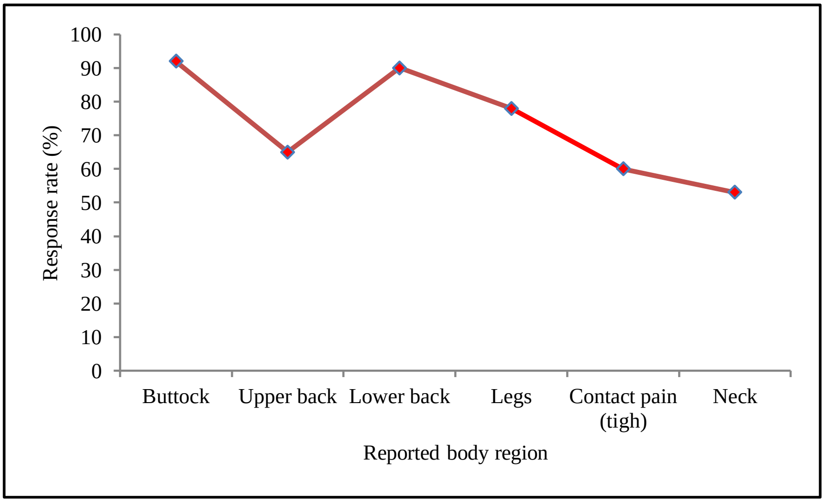

Figure 8. Body regions requiring better comfort from an IFaDes chair

3.5 Anthropometric Data of Fashion Designers

The assessment of anthropometric data of the 251 participants was aimed at getting the required data for the design of the IFaDes chair. The necessary body dimensions obtained are shown in Table 1. The means, standard deviations, 5^{th} to 90^{th} percentile collected are likewise disclosed below.

Table 1. Measured anthropometric data of FaDes (n = 251)

	KH	PH	BPL	BKL	BB	SB	BH	FL
Mean	51.27	46.95	44.13	51.30	27.51	28.68	22.48	36.08
SD	5.75	6.98	5.33	9.69	5.08	5.00	6.59	10.05
5^{th}	43.95	36.30	35.00	39.85	19.00	22.00	14.95	22.95
25^{th}	50.50	48.00	42.00	50.00	25.00	26.00	18.00	27.00
50^{th}	52.00	49.00	44.00	54.00	28.00	30.00	21.00	40.00
75^{th}	53.50	51.75	47.00	57.50	29.00	32.00	24.00	43.00
90^{th}	56.00	53.00	49.49	60.00	30.00	33.00	33.00	45.00

KH – knee height, PH – popliteal height, BPL – buttock-popliteal length, BKL – buttock knee length, BB – buttock breadth, SB – seat breadth, BH – buttock height, FL – forearm length

Table 2 shows additional details regarding the FaDes' working table that houses the sewing machine. The data formed a part of the design criteria for the IFaDes chair. The dimensions were used to scale the chair to fit the majority of the respondents' anthropometric data with the 90^{th} percentile as the active percentile.

Table 2. Characteristics dimensions of FaDes' workbench

	WTL	WTH	WFL
Mean	77.88	73.68	51.07
SD	10.92	8.21	6.04
5^{th}	58.00	60.95	34.95
25^{th}	75.00	72.50	51.00
50^{th}	83.00	75.00	53.00
75^{th}	85.00	76.00	53.00
90^{th}	85.00	83.00	55.00

WTH – work table length, WTH – work table height, WFL – workspace for leg

3.6 Design Parameter Analysis

Using the qualitative and quantitative data collected through questionnaires and anthropometric measurement, respectively, the dimensions of the chair segments were determined using the theory of solid mechanics and complaint mechanism. The tension stress exerted was derived using Equation 1. Mild steel was considered for the design due to its ductility and cost-effectiveness.

$$\sigma_{tension} = \frac{F}{\chi d} \tag{1}$$

where:

χ = thickness (mild steel; 3 mm)
F = applied force (average force exerted by FaDes; 63 kg)
d = width (seat breadth [SB]; 330 mm)

$$\sigma_{tension} = \frac{63 \times 9.81}{3 \times 330}$$

$$\sigma_{tension} = 0.6243\ Nmm^{-2}$$

Crafted using Solidwords, the IFaDes chair's isometric view is shown in Figure 9 while Figure 10 exhibits the stress analysis of the chair. The stress analysis was done to ensure that the maximum tensile stress is just adequate.

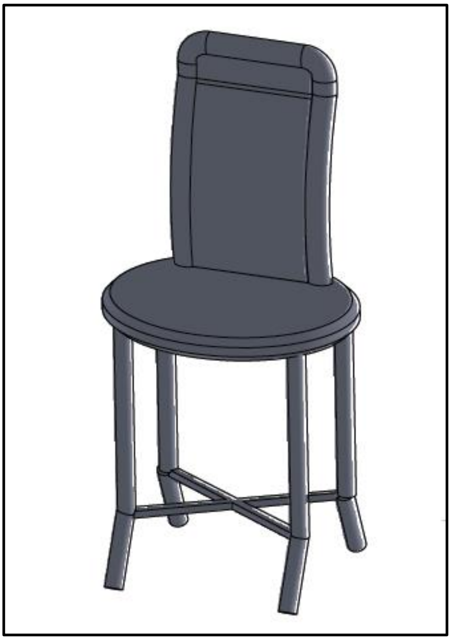

Figure 9. Isometric view of the IFaDes chair using anthropometric data of respondents

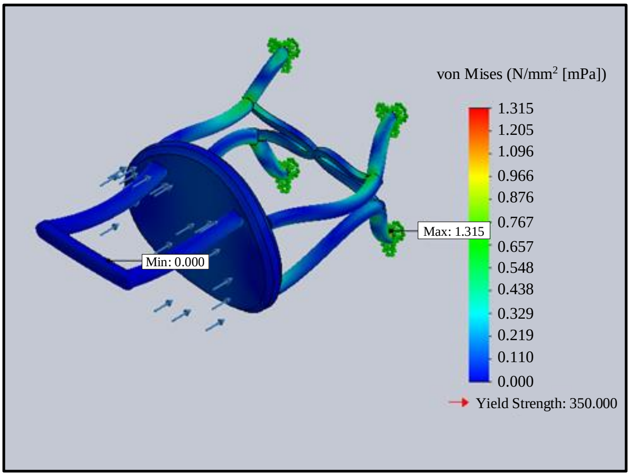

Figure 10. Stress analysis of the IFaDes chair with backrest

3.7 Fabrication and Performance Evaluation of the IFaDes Chair

It was observed that sitting for long hours is common among FaDes. Jobs are carried out in a forward bending position while subsequent operations such as netting is done by sitting on the chair. According to Choobineh (2004), improper chair design can affect designers' functions and cause backache. As evidenced by the result of this study, the high level of reported musculoskeletal disorder among FaDes may have been majorly influenced by bad sitting posture caused by the prolonged sitting position on the non-ergonomic chairs.

This assessment led to redesign and fabricate an improved chair as shown in Figure 11. The 90th percentile was used as it reflected the data from a larger number of FaDes. The values of the buttock and seat breadth obtained from the anthropometric data were utilized for the seat's dimension while the seat height was acquired from the value of the popliteal height. The legs of the seat were inclined at an angle of 30° for a better balance. The inclination angle also provided support for a better distribution of load or weight. Provision was made for the support of the torso. The curvature of the torso was slightly above the buttock height. It was opined to reduce the musculoskeletal disorder and back pain disorder as reported by the respondents. Hence, the backrest of the chair was at angle 15° – sufficient enough to support the torso. This was an important consideration in designing the IFaDes chair. This is a preferred standard for backrest as specified by Ismaila *et al.* (2013) and CUErgo (2018).

The IFaDes chair was fabricated using mild steel and other local materials. The components of the backrest of the improved chair were soft foam, upholstery, screw and wood support. The same materials were utilized for the seat base with the addition of sheet metal plate.

Figure 11. Fabricated IFaDes chair with backrest front (a) and side view (b)

Figure 12 shows the performance evaluation of the fabricated IFaDes chair. The IFaDes chair was subjected to performance evaluation. It was made accessible to users for a minimum of 168 h. Feedback from the users showed that the IFaDes chair provided better support to their back and torso. They emphasized that it was more convenient with minimal pain experienced in the buttock, hand/finger, legs, neck, lower back, waist and upper back regions as shown in Figure 12.

3.8 Cost Analysis

The cost incurred in the fabrication process is specified in Table 3.

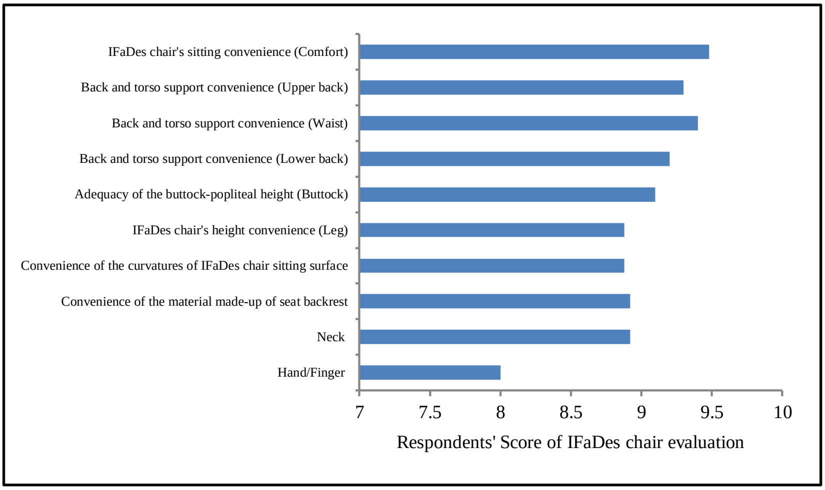

Figure 12. Respondents' evaluation on the convenience of the fabricated IFaDes chair

Table 3. Cost of materials

S/N	Item	Quantity (mm)	Rate (Nigerian Naira)
1	Hollow steel pipe (25 x 25 x 1.5 mm)	1.5	2,400
2	Seat upholstery	1	400
3	Backrest upholstery	1	550
4	Screw set	10	50
5	Painting	1	200
6	Welding Electrode	4	400
7	Sheet Plate (250 x 250 x 1 mm)	0.5	300
Total			4,300

4. Conclusion

The evaluation of the FaDes chair and its effects on users were carried out in this study. Based on the obtained result, the majority of the local FaDes experienced various discomforts in using the FaDes chair with neck, leg, hand, waist, back and waist pain as the most prevalent. Hence, using locally available materials, an affordable IFaDes chair was developed utilizing the data collected from the respondents through questionnaire and anthropometric analysis. Among the ergonomics features considered in the design of IFaDes were the provision of torso support to reduce or eliminate waist and back pains. Respondents reported that when utilized, the chair would reduce work stress and improve users' health.

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