

## DESIGN AND ERGONOMICS IN INDUSTRIAL DESIGN PRODUCT DEVELOPMENT METHOD IN MAKURDI METROPOLIS OF BENUE STATE

**Dese David Dzenda**

Department of Fine and Applied Arts,  
College of Education, Katsina-Ala,  
Benue State.

**Terungwa Oragbe**

Department of Fine and Applied Arts,  
College of Education, Katsina-Ala,  
Benue State.

Corresponding e-mail: [dezenda@gmail.com](mailto:dezenda@gmail.com)

### Abstract

*This survey examines the relationship between design and ergonomics in the product development peculiarly the industrial design method. It pays attention to user experience of contemporary product, particularly tangible products considering factors ranging from convenience of use to economic aspects. Through a review of relevant available literature, and non-participant observational method, it was gathered that form, style, functionality and cost play an essential role in the contemporary product development procedure. The study aimed to affirm the imperative of ergonomics in product designing and development, thus provide information to local stakeholders in the product development field to improve user experiences of the product. The conceptual framework of the study essentially considered ergonomics and anthropometrics theory. The theory puts the customer or human factor in the centre of the product development procedure as a major factor to consider in enhancing quality product outcomes. Through this survey, some products were observed to hold no alluring quality to the customer or potential user. However, the phenomenon was voided in some products through the initial introduction of ergonomics principles. The study outlined shortcomings to a more effective ergonomic compliant industrial design product development programme in Nigeria, to include policy issues, limitations of the curriculum, inadequate research, lack of awareness and machinery among Nigeria product developers. In conclusion, it was established that ergonomics has the potential of enhancing design quality in product development, and ways to improve the quality of a product were outlined. The study suggested the inclusion and proper application of ergonomics by producers in product design and development programme and policies, to enhance product user experience.*

**Keywords:** Ergonomics, Product Development, Enhance, User Experience, Industrial Design.

### INDRODUCTION

Ergonomics is an imperative aspect of designing that helps to reduce unsatisfactory design in a product. The acquisition of knowledge of ergonomics and its application by designers has helped them improve skills in product development (PD), (Zhou, Chen, Lv, & Cao, 2016). It is established that, many contemporary products including furniture, equipment, and machines have been developed in advanced technological countries, using ergonomics principles, thus, providing empirical evidences to uphold the imperative of ergonomics. It is important to know that to apply ergonomics, the designer requires good knowledge of the concept, to know the individual, group of people, and to consider the variables, through specified data. Doubtless, considering ergonomics in industrial design (ID) PD is complex. Cooper (2019) outlines challenges of PD to include speed

of globalization and ambiguities. Whereas clients emphasize the cost of production, the end-user considers the functionality, while the industrial designer concedes to the methodology and process, his focus is on making the design good, as Demirbilek and Sener (2003) observes. Yet, satisfactory design cannot be attained if the end user, referred to as the ‘human factor’ Gomes (2021) is not considered in the design process. The process includes data gathering and making several attempts, since there is no great design without the process of trials, and refining to achieve desired results. At the present, technology is available to provide the required information for the knowledge of ergonomics and to assist in obtaining data for application of ergonomics in ID-PD method.

### **STATEMENT OF THE PROBLEM**

Locally produced products may be functional but lack comfortability to the user. Many products locally developed in Nigeria reflect poor ergonomics, essentially due to lack of requisite knowledge, training, or research among the local product developers. Ogunduyile, Kayode, and Ojo, (2008) attest that many designers in Nigeria are ‘roadside’ and even the trained designers lack the skills to apply ergonomics in their design activities. A number of product developers in Nigeria are unaware of ergonomic aspect as a tool, and how to apply it for enhancing product quality. This renders our locally developed product less attractive to customer, and do not compete on the contemporary global market space. The ergonomics of our local products thus, beckons critical and innovative strategies, for improvement.

### **OBJECTIVES OF THE STUDY**

From observation and review, the study aimed to:

- i) Affirm the place of ergonomics in industrial design PD.
- ii) Reveal the unfamiliarity of ergonomics among local product developers, within the study location.
- iii) Provide simple methodology for local production of user-convenient products.

### **RESEARCH QUESTIONS**

The following research questions were formed to guide the study and in providing solution to the research problem:

- i. How essential is ergonomics to ID PD?
- ii. To what extent are local product developers familiar with ergonomics in product?
- iii. What method is coherent for local production of user convenient product?

### **CONCEPTUAL CLARIFICATION**

#### **Ergonomics and Anthropometrics**

##### ***Ergonomics***

Ergonomics has been defined as the scientific discipline regarding the knowledge of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data, and methods to design, to optimize human well-being and overall system performance. (Caple, 2010) in International Ergonomics Association (IEA). Tosi and Tosi (2020) affirm that components of ergonomics includes human factors (HF), human-centred design (H-CD), user experience (UX), and all the methods and process assessing the needs and expectations of people as they interact with a product. Broadly, ergonomics focuses on human beings and their interaction with machines, materials, information, and procedures used in work and everyday activity (Wilson, 2000). Bridger (2008) further attests that ergonomics focuses on the interaction between the person and the machine and the design of the interface between the

two. The main objective of ergonomics to PD is to improve the comfortability of using a product. Available literature noted that when ergonomics is applied to product design and development (PDD), it upturns efficiency, productivity and reduces errors and accidents. Ergonomics is a key factor in the design of all products, including furniture, handheld gadgets, knapsack sprayers, push trucks etc. Ergonomics is thus, an essential part of the PDD as relates to the physical fit of the human body concerning the comfort experiences of a user. The general approach to basic ergonomic principles and concepts is outlined in Tosi and Tosi (2020). This applies to the design and evaluation of products, tools, equipment etc., to make them compatible with the characteristics, the needs, values, abilities and limitations of people. These basic principles were set with the intention to improve the safety, performance, effectiveness, efficiency, reliability in products, while safeguarding and enhancing the health, well-being, and satisfaction of prospective users.

It is established that, the continuous use of some products can cause harm to the health by persistently subjecting the human body to positions and situations that are not comfortable. Peteri, (2017) in *Bad Enough Ergonomics*, discusses an office chair and its resultant stress to the human body. VirvePeteri refers to ergonomics as a ‘biomedical framework, which focuses on humans. The musculoskeletal system (e.g. lower back pain) and psychological illness such as stress, possess a great threat to human health. Minetto, Giannini, McConnell, Busso, Torre, and Massazza, (2020) discusses common musculoskeletal disorders in the elderly, and Soares, Pereira, Gomes, Marcondes, de Campos Gomes, and de Melo-Neto (2019) argue the most prevalent types of work-related injuries is musculoskeletal disorder. Evidently, the human body reveals the effects of the bad posture with damaging effects. These conditions can be caused by poor ergonomics in product design. With the proper method of incorporating ergonomics the condition will be avoided.

**Concept of Anthropometrics**

Anthropometric is the study of the human body measurements and its movement. Ryan (2013) opines that anthropometrics often involve research into measurements relating to people. It involves collecting statistical information relevant to the human body, referred to as ‘anthropometric data’. This is imperative to obtain data to design and develop products that are ergonomics compliant. It is the use of body measurements to determine the optimum size of product parts, or products, for comfortable and efficient use. The table below show sample anthropometric data generation tool used in this survey:

**Table 1: Anthropometric Data Generating Tool**

Gender	Age	Question	Response
		How far can the person reach	
		How much space people need	
		Height of a person, how tall	
		How much force they can exert	
		Length of arms/ legs	
		What is the size of palm	

The application of anthropometrics as reviewed in a study by Fidelis and Ogunlade (2022), discusses anthropometric perspective to classroom furniture ergonomics in Nigerian schools. They suggested standards for students in the various classes.

Ergonomics as viewed by Wanberg, Caston, and Berthold, (2019) is the application of anthropometric data to determine a design and its outcome. For instance, measurements of the palm can be used to design the shape and size of a push truck handle. Essentially, the application of anthropometric data when designing is aimed to achieve a good product. During the design process, ergonomics is incorporated using the established guiding principles.

### **Ergonomics, Posture, and Movement**

Human posture and movement are said to be the two most imperative factors in considering ergonomic design. Ezugwu, Egba, Igweagu, Eneje, Orji, and Ugwu (2020) discuss ergonomic factors associated with musculoskeletal disorders and affirm that good posture and efficient movement are closely related to the success of tasks. It is established that, ligaments, tendons, and muscles of the body constantly adapt to positions that the body subjects them to. Quite often, products that possess poor ergonomic characteristics subject the user to mechanical stress on joints and muscles (Acosta, Morales, Lagos, and Ortiz, 2011). According to Cooper (2019) in the drivers of success in new-product development (NPD), concepts such as agile development, design thinking for ideation, open innovation, and lean product development are recent practices aimed to address emerging challenges in PDD.

### **Product Design and Development (PDD)**

PDD as viewed by Alli (2018), deals with many aspects, not only concerning the creating of new product innovation but also conceptualizing the redesigning of a product. PD is reviewed as a process of creating a new product to be sold to customers. Whereas, design refers to those activities involved in creating the styling, look and feel of the product (Robert Q. Riley Enterprises, 2021), the product's mechanical structure, materials and processes, and the interaction of the various components necessary to make the product work are all decided by the designer. Morris (2009) opines that product designers through a systematic approach, conceptualize and evaluate ideas, turning them into tangible inventions and products. On the other hand, development in this context refers to the entire process of identifying a market opportunity, creating a product to appeal to the identified market, testing, modifying, and refining the product until it is ready for production. Goffin and New (2001) view PD as the creation of products with new or different characteristics that offer new or additional benefits to the user. It may involve modification or formation of an entirely new product that satisfies a newly defined customer's want or market in customer support. Medase and Barasa (2019) discuss PDD as a planned and premeditated activity geared towards the creation of a product. (Cooper, 2019) opines that it is essentially the efficient and effective generation and development of ideas through a process, that leads to new products.

Industrial design (ID) is a process of design which is applied to product with the aim of manufacturing and mass production. ID involves the creative activity of determining the products' form, size, function, and style. Pasa, (2020) attests that at the 29th General Assembly in Gwangju, South Korea, 2015, the Professional Practice Committee proposed a modified definition of ID as a strategic problem-solving process that drives innovation, improves business success and leads to a better quality of life through innovative products, systems, services and experiences (Pasa, 2020). ID endeavours to bridge the gap between imagination and reality (Muminovic, Saric, Mesic, Pervan, and Delic, 2019). It is important to note that, ID and PD, are related but with slight differences. Muminovic, et al. (2019) opine that engineering knowledge is necessary and most important in ID, thus industrial designer can be product designer, whereas, engineering knowledge is not essential in product design, thus product designer may not be industrial designer. ID overlaps PD, with the aim of problem solving, improving, and enhancing marketing potentials of a product.

PDD in the field of ID, is an aspect that is concerned with bringing artistic form and usability associated with craft and design, and ergonomics to mass-produce products (Melluso, Pardelli, Fantoni, Chiarello, and Bonaccorsi, 2021). Stakeholders in product design and development, are both the product Designer, the potential user, client and the target market. While the client is concerned with production cost, in the end, the customer looks at the price, appearance, and value of the product, and the end-user is concerned with the usability and functionality of the product. Norman (2002) cited that product Designers need to consider all of the details, including the way people use objects, faulty designs, and the desirable ways in which people wish they could use the product. Pirkl (1994) also noted that products are ideally designed to benefit people of all ages and abilities without affecting any group. Although engineering PD also integrate ergonomics principles, the methods they use differ from ID methods particularly aesthetic consideration. The ID PD is conscious of “good design” as reviewed in Meyer and Norman (2020). Sun, Houssin, Renaud, and Gardoni, (2019) outlined methodologies for integrating human factors and ergonomics in engineering PD with little regard to aesthetics. The lack of aesthetics consciousness in IDPD is even more obvious with the case of Nigeria.

### Ergonomics Designing Process Tools

Vaneker, Bernard, Moroni, Gibson, and Zhang, (2020), show that the design process is usually completed by a group of people, including industrial designers, field experts (e.g. prospective users), engineers, etc. depending upon the products involved. The process focuses on figuring out what is required, brainstorming possible ideas, creating mock prototypes, and then generating the product. The product designer then needs to execute the idea, turning it into an actual product; he then evaluates its efficiency by checking to see if any improvements are necessary. The design process also follows a guideline involving three main sections including analysis, concept, and synthesis as outlined in the table below:

**Table 2: Ergonomic Design Process Requirement**

Design Process	Involvement	Step
Analysis	Accept situation	This is when the designer decides on committing to the project and finding a solution.
	Analyze	At this stage, everyone in the team begins research.
Concept	Defining	Here the key issue is defined, the situation of the problem becomes the objective(s)
Synthesis	Ideate	At this point, the designer brainstorms different ideas, solutions for their design problem.
	Select	Select from the wide range of ideas a few options, with potentials to succeed
	Implement	Prototypes are built at this stage and plans are outlined for actual production.
	Evaluate	The products are tested and improvements are made. That does not mean the process is over, adjustments may be required.

### Theory of Demand-pull and Technology-push

Demand-pull innovation and technology-push innovation were theories originated by Archer (1974), he observed that most PDs, transpire as a result of fall under one of either demand-pull or technology-push.

*Demand-pull* is the stimulation of innovation by market forces to be explored by the design of a product (Dai, Li, and Chen 2021). This PD model attempts to solve a design problem by the development of a new product or developing a product that is already in the market, such as improving an existing invention for another purpose.

*Technology-push* happens when there is an advancement in intelligence. This can occur through research or it can occur when the product designer comes up with a new product design idea (Singla, Ahuja, and Sethi, 2019). The Product Designer's part is to bridge art, science, and technology to generate new products that people can use.

Available literature reviewed shows that, Fidelis, Ogunlade, Adelokun, and Mesquita-Guimarães (2019) conducted a study and presented their anthropometric measurements for the design of ergonomic classroom furniture for University students in Nigeria. They opined prevalent description of anthropometric data of young Nigerian adults at any given era to enhance ergonomic furniture designs.

Similarly, Obinna, Sunday, and Babatunde (2021), conducted a survey on secondary school children in Akure, Nigeria. The aim of the study was to survey and describe their anthropometric dimensions and to evaluate the ergonomic suitability of classroom furniture available to the study participants. They suggested the need to have a policy on education furniture design in Nigeria to address this inadequacy.

Akinyemi, Adeyemi, Raheem, Adeaga, and Adie (2020), went further in using locally available materials to develop an affordable IFaDes (Improved Fashion Design) chair utilizing the data they collected from the respondents through questionnaire and anthropometric analysis, with aim to reduce work stress and improve users' health.

Although the chair is as common as a study product, similar in this survey, a study on push-truck is unperceived. Yet, none of the reviewed studies were conducted within the study location as in this survey, and were focused aside of ID field, and with divergent aims. Furthermore, a simplified, common method of applying ergonomics to local PDD is lacking in the review hence a gap of knowledge that beckons this study.

### METHODOLOGY

The non-participant observational method as noted by Handley, Bunn, Lynch, and Goodman, (2020) which is a form of a qualitative instrument was used. Participants are usually observed on ongoing behavior in a natural setting. In addition, review of existing literature on ergonomics, anthropometrics, good design, product development, and empirical results from previous studies was done. Oral interview was also employed. Participants were observed as they interacted with the selected products which included armless chair, and push-truck (amalaki). The selection of these products was because they are commonly used locally. More so, users are perceived to have problem with using the products. Shape, style, perimeters, measurements, of the selected products were observed and recorded, in relation to ergonomics and anthropometric standards. Data was equally gathered from participants through semi-structured interviews. 15 participants, comprising 5 product developers and 10 uses, were involved. A review of 25 texts comprising current articles in relative Journals was carried out. Oral interviews of the selected participants ranging between 15-30 minutes with each respondent was administered. This was to

ascertain level of familiarity local designers and prospective users have concerning ergonomics and anthropometrics, and the effect poorly developed product may have on them. The scope of this survey was limited to Makurdi metropolis, Benue State.

**RESULTS**

**Observation**

Results from observation of the 15 participants is shown in the table below.

**Table 3: Response on Comfortability among selected Users of Armless Plastic Chair, and Push-truck**

S/N	Item	Uncomfortable	Comfortable	Neutral
1.	Plastic arm less chair	9	4	2
2.	Push-truck (amalaki)	7	3	5

Result from Table 3 shows the extent users are comfortable with the products studied. The study revealed that only 4 of 15 users were comfortable with with the armless chair selected, while only 3 of 15 indicated they were comfortable with the push-truck.



**Plate 1:** Showing locally developed Armless-chair with respondents’ posture



**Plate 2:** showing Amalake (push-truck) with respondent pushing.

**Table 4: Response on Familiarity among selected local product developers in Makurdi**

S/N	Question	Yes	No	Neutral
1.	Are you trained in product development?	3	2	0
2.	Your field is Engineering	2	3	0
3.	Your field is ID	0	4	1
4.	You are Artisan	3	2	0
5.	Do you know ergonomics?	2	3	0
6.	Do you gather anthropometric data for developing your product?	0	4	1

Result from Table 4 shows the extent product developers in Makurdi metropolis are unfamiliar with ergonomics. The study revealed that only 2 of 5 product developers were familiar with the ergonomics, yet they ignore gathering data or applying anthropometrics, while 1 respondent was neutral.

## FINDINGS AND DISCUSSION

1. Data analysis in Table 3, revealed that respondents agree that the selected products lacks the desired comfort. This shows that the design lack ergonomics and agrees with Peteri, (2017) in *Bad Enough Ergonomics*.

2. From observation, respondents appeared to be less relaxed on the chair. Also, The height and handle of the push-truck, appeared to be uncomfortable for them to push. Respondents agreed that the use of these products caused pain on their shoulders, hand, and back. This agrees with Ezugwu *et al*, (2020) in their submission on effect of bad posture on human, particularly as it can cause back pains. However, the shorter user was comfortable in using the push-truck, indicating appropriate dimension with their anthropometric data.

3. From the results in Table 3, and observation, the researchers discovered that local designers lacked the knowledge and application of ergonomics and anthropometric in developing products. This is in agreement with Ogunduyile, *et al* (2008) who stated that many designers in Nigeria are ‘roadside’ and even the trained designers lack the character to apply ergonomics in their design activities. This shows that the centrality of the user was compromised in the design process, and Gomes (2021) opines that satisfactory design will not be achieved without considering end-users.

4. Results in Table 4, are selected local product developers, indicated that they do not employ ergonomics in their product development process. Moreso, most of the product developers were not from ID field, but of engineering or artisan backgrounds.

## CONCLUSION

This study was carried out to survey the integration between design and ergonomics in ID product development process. Ergonomics is key to the design of user comfortable products. Undermining aspects of ergonomics such as anthropometrics data in development of a product, results to uncomfortable product and may further cause health challenge(s) to user. This clearly indicates that design and ergonomics in product design and development are integrated. The study



was essentially guided by three objectives and three research questions. The non-participant observational method was used to collect relevant data. Two products and a total of thirty-five respondents were used in the study. Thirty respondents were observed as they interacted with the two products. Five local designers were orally interviewed on their knowledge of ergonomics application. Designers need to uplift to the field of ergonomics application to improve their product development skills.

### RECOMMENDATIONS

1. Ergonomics application research should be thoroughly carried out by product developers before production. This will enable them adequately and appropriately employ ergonomic processes.
2. Product developers are encouraged to attend training to obtain information and education on procedure to employ ergonomics in their work. Ergonomics should be encouraged and emphasized in ID study curriculum in Nigeria. Furthermore, a check and regulatory body should be established to ensure compliance to ergonomics in PD.
3. The non-participant observational methodology should be employed in testing user-comfortability from prototypes. With improved technology, and scientific advancement, ergonomics is achieved easier. Designers should thus, embrace these technologies to enhance their work.
4. There is need for safety, well-being and convenience of the user. The government should therefore involve professional designers who have adequate knowledge and training in ergonomics application, to head check and regulatory organizations.

### REFERENCES

- Acosta, G. G., Morales, K. L., Lagos, D. E. P., & Ortiz, M. R. R. (2011). Addressing human factors and ergonomics in design process, product life cycle, and innovation: trends in consumer product design. In *Human Factors and Ergonomics in Consumer Product Design* (pp. 133-154). CRC Press
- Akinyemi, O. O., Adeyemi, H. O., Raheem, W. A., Adeaga, O. A., & Adie, U. O. (2020). Towards Reducing Musculoskeletal Disorders Among Local Fashion Designers in South-Western Nigeria. *Mindanao Journal of Science and Technology*, 18(2).
- Alli, H. (2018). Evaluation theories of product definition method for a successful new product. *AlamCipta: International Journal on Sustainable Tropical Design Research and Practice*, 11(1), 23-28.
- Archer, B. (1974). Design awareness and planned creativity in industry. (p. 87). Toronto: Thorn Press Limited.
- Bridger, R. (2008). *Introduction to ergonomics*. Crc Press.
- Caple, D. C. (2010). The IEA contribution to the transition of Ergonomics from research to practice. *Applied ergonomics*, 41(6), 731-737.
- Cooper, R. G. (2019). The drivers of success in new-product development. *Industrial Marketing Management*, 76,36-47.
- Dai, X., Li, Y., & Chen, K. (2021). Direct demand-pull and indirect certification effects of public procurement for innovation. *Technovation*, 101, 102198.

- Demirbilek, O. & Sener, B. (2003). Product design, semantics and emotional response. *Ergonomics*, 46(13-14), 1346-1360.
- Ezugwu, U. A., Egba, E. N., Igweagu, P. C., Eneje, L. E., Orji, S., & Ugwu, U. C. (2020). Awareness of awkward posture and repetitive motion as ergonomic factors associated with musculoskeletal disorders by health promotion professionals. *Glob. J. Health Sci*, 12, 128.
- Fidelis, O. P., & Ogunlade, B. (2022). Anthropometric perspective to classroom furniture ergonomics and the need for standards in Nigerian schools. *Work*, 72(1), 279-289.
- Fidelis, O. P., Ogunlade, B., Adalakun, S. A., & Mesquita-Guimarães, J. (2019). Anthropometric measures of young Nigerians for ergonomic furniture design. *Journal of Biology and Medicine*, 3(1), 055-061
- Goffin, K. & New, C. (2001). Customer support and new product development: An exploratory study. *International Journal of Operations & Production Management*.
- Gomes, C. C. (2021). Remote Work: The Need of Human Factors and Ergonomics to Improve Human Health and Wellbeing. In *Advances in Ergonomics in Design: Proceedings of the AHFE 2021 Virtual Conference on Ergonomics in Design, July 25-29, 2021, USA* (pp. 951-958). Springer International Publishing.
- Handley, M., Bunn, F., Lynch, J., & Goodman, C. (2020). Using non-participant observation to uncover mechanisms: insights from a realist evaluation. *Evaluation*, 26(3), 380-393
- Medase, K., & Barasa, L. (2019). Absorptive capacity, marketing capabilities, and innovation commercialisation in Nigeria. *European Journal of Innovation Management*, 22(5), 790-820.
- Melluso, N., Pardelli, S., Fantoni, G., Chiarello, F., & Bonaccorsi, A. (2021). Detecting bad design and bias from patents. *Proceedings of the Design Society*, 1, 1173-1182.
- Meyer, M. W., & Norman, D. (2020). Changing design education for the 21st century. *She Ji: The Journal of Design, Economics, and Innovation*, 6(1), 13-49.
- Minetto, M. A., Giannini, A., McConnell, R., Busso, C., Torre, G., & Massazza, G. (2020). Common musculoskeletal disorders in the elderly: the star triad. *Journal of clinical medicine*, 9(4), 1216.
- Morris, R. (2009). *The fundamentals of product design*. AVA Publishing. ISBN 2-940373-17-5.
- Muminovic, A. J., Saric, I., Mesic, E., Pervan, N., & Delic, M. (2019). Research about characteristics of designs from industrial designers and product designers. *Periodicals of Engineering and Natural Sciences*, 7(2), 860-869
- Norman, D. (2002). *The design of everyday things*. (p. 28). New York: Basic Books.
- Obinna, F. P., Sunday, A. A., & Babatunde, O. (2021). Ergonomic assessment and health implications of classroom furniture designs in secondary schools: a case study. *Theoretical Issues in Ergonomics Science*, 22(1), 1-14
- Ogunduyile, S. R., Kayode, F., & Ojo, B. (2008). Art and design practices in Nigeria: The problem of dropping out. *International Journal of Education and the Arts*, 9(4), 1-21.
- Pasa, B. (2020). Industrial Design and Artistic Expression: The Challenge of Legal Protection. *Brill Research Perspectives in Art and Law*, 3(2-3), 1-137.

- Peteri, V. (2017). Bad enough ergonomics: A case study of an office chair. *Sage Open*, 7(1), 2158244016685135.
- Pirkkl, J. (1994). *Transgenerational design: Products for an aging population*. Van Nostrand Reinhold Company.
- Qaddo, M. (2019). Participant observation as research methodology: assessing the validity of qualitative observational data as research tools. *Dubai International Academic City, Dubai, United Arab Emirates*.
- Robert Q. Riley Enterprises. "The Generic Process for Developing New Products Provides a Road map from Conceptualization and Design to Market Positioning and Strategy", <https://www.rqriley.com/pro-dev.htm>
- Ryan, V. (2013). Anthropometrics and ergonomics  
[https://technologystudent.com/pdf11/rev\\_cards\\_ergo1.pdf](https://technologystudent.com/pdf11/rev_cards_ergo1.pdf)
- Singla, A., Ahuja, I. S., & Sethi, A. S. (2019). An evaluation of status of technology push and demand pull practices for sustainable development in manufacturing industries. *International Journal of Technology, Policy and Management*, 19(1), 32-71.
- Soares, C. O., Pereira, B. F., Gomes, M. V. P., Marcondes, L. P., de Campos Gomes, F., & de Melo-Neto, J. S. (2019). Preventive factors against work-related musculoskeletal disorders: narrative review. *Revista Brasileira de Medicina do Trabalho*, 17(3), 415.
- Sun, X., Houssin, R., Renaud, J., & Gardoni, M. (2019). A review of methodologies for integrating human factors and ergonomics in engineering design. *International Journal of Production Research*, 57(15-16), 4961-4976
- Tosi, F., & Tosi, F. (2020). *Design for ergonomics* (pp.31-45). Springer International Publishing.
- Ulrich, K. (2003). *Product design and development*. Tata McGraw-Hill Education.
- Vaneker, T., Bernard, A., Moroni, G., Gibson, I., & Zhang, Y. (2020). Design for additive manufacturing: Framework and methodology. *CIRP Annals*, 69(2), 578-599.
- Wilson, J. (2000). Fundamentals of ergonomics in theory and practice. *Applied ergonomics*, 31(6), 557-567.
- Zhou, D., Chen, J., Lv, C., & Cao, Q. (2016). A method for integrating ergonomics analysis into maintainability design in a virtual environment. *International Journal of Industrial Ergonomics*, 54, 154-163.