# SEARCH AND DETERMINATION OF ERGONOMIC AND ANTHROPOMETRIC REQUIREMENTS IN THE DESIGN OF PRODUCTS TO MAKE AEROBIC EXERCISE: A REVIEW OF LITERATURE.

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**Resumen** Diseñar se ha convertido en una actividad que ha evolucionado en las últimas décadas. Esta evolución ha cambiado con el paradigma de solo crear y diseñar contra diseñar y crear para satisfacer las necesidades del usuario, integrando responsabilidad social, compatibilidad con el medio ambiente, sustentabilidad, funcionalidad y economía. Ante esta serie de restricciones, surge la necesidad de contar con información fidedigna de las consideraciones mínimas para un diseño exitoso. En este tenor, la creación de diseños dirigidos al uso directo por parte de seres humanos, hace necesario que estos integren principios ergonómicos por su funcionalidad y adaptabilidad. Ante la necesidad de determinar cuáles son las características con las que debe contar el diseño de aparatos para hacer ejercicio, primero se realizó el despliegue de la función de calidad (por sus siglas en ingles QFD) para definir cuáles son las necesidades del cliente. A partir de los resultados obtenidos del QFD, se desarrolló la revisión de literatura asociada, bajo la operación de búsqueda sistemática en la que el objetivo fue identificar información relevante para el diseño de este tipo de productos. Debido a que el diseño depende de la subjetividad del diseñador, se complementó la investigación asociando la técnica de diseño axiomático, la cual es una metodología compleja y recientemente empleada para hacer objetivas las necesidades de los usuarios finales. Se identificaron 18 artículos que exponen la integración del diseño axiomático, la ergonomía y la antropometría como principios para el diseño de productos. Estos provenientes de una revisión de 108 artículos encontrados en 5 bases de datos, publicados en el periodo 2010-2018.

***Palabras clave:*** *Ergonomía, antropometría, diseño, diseño de producto, diseño axiomático.*

**Relevancia para la Ergonomía:** La información obtenida presenta una fuente de información sintética, que puede ser considerada por los diseñadores de productos para ejercicios, con la certeza de que se declaran implícitamente los principios de ergonomía y antropometría.

**Abstract** Design is an activity that has been changed in the last decades. This evolution has changed the paradigm of only create and design versus design and create to satisfy the user necessities, integrating social responsibility, environment, sustainability, functionality, and economy. With these restrictions, there is a need to have reliable information on the minimum considerations for a successful design. In this regard, the creation of designs aimed at direct use by human beings makes it necessary the integration of ergonomic principles for their functionality and adaptability. The present work arises from the need to determine what are the characteristics with the design of exercise equipment should count, for this, the information obtained from the of the quality function deployment (QFD) was considered to define the client's needs. With these results, a literature review was developed using systematic research technique with the aim to identify relevant information for the design of exercise products. Due that the design depends on the subjectivity of the designer, the research was complemented considering the axiomatic design methodology. 18 articles were identified, those articles expose the integration of axiomatic design, ergonomics, and anthropometrics as a principle for the product's design. Those papers come from a review of 108 documents founded in 5 databases, published in a period from 2010 to 2018.

**Keywords:** Ergonomics, anthropometry, design, product design, axiomatic design.

**Relevance to Ergonomics.** The information generated is a resource of synthetic information that could be considered by exercise product designers, with the certainty that the principles of ergonomics and anthropometry are implicitly declared.

## 1. INTRODUCTION

Designing exercise products for a population with a diffuse range of characteristics, represents a challenge for market analysts, designers, manufacturers also, for the participant as a user’s of future products. The design of a product for exercising must be a subject to different restrictions. In this way, the inclusion of social responsibility, sustainability, environment and, functionality, have become the trigger for the inspiration of the designers and creators to establish rules and protocols for the development of their products. Given these considerations, this research describes information associated with obesity and overweight as part of the social element, the use of ergonomics and anthropometry as part of sustainability and finally the use of axiomatic design as a critical element of functionality.

### 1.1 Obesity and overweight versus physic activity.

On this subject, it is essential to define the concepts carefully. Overweight and obesity are defined as an abnormal or excessive accumulation of fat that can be detrimental to health. Both are global health indicators. The determination of those indicators is based on the percentage of the total population that has a body mass index (BMI). Where 25 to 30 is the BMI for overweight and, higher than 30 is for obesity – The BMI is calculated by dividing the weight in kilograms by the square of the height in meters (kg / m2) –
(Organización Mundial de la Salud, 2017).

At present, many of the countries have integrated education plans, health plans, security plans, etc., into their policies. It is not a coincidence that within the health plans there is concern about the rates of overweight and obesity. According to, World Health Organization (WHO), (2017), 57% of the world population lives in countries where overweight and obesity cause more deaths than weighted insufficiency (insufficiency generated by being below the weight that is considered healthy).

According to the WHO and the Food and Agriculture Organization of the United Nations (FAO, 2017), obesity is a disease that affects a large part of the population of the countries of the world and presents a trend that is increasing. In many cases, it is a risk factor for developing other diseases such as diabetes, ischemic heart disease and certain cancers that are attributable to overweight and obesity.

On the other hand, the World Health Organization (WHO) has declared that the two leading causes to generate overweight are eating habits and the level of sedentary lifestyle, coupled with the malfunction of some parts of the body(Organización Mundial de la Salud & Organización Panamericana de la Salud, 2016).

In Mexico, the prevalence of overweight and obesity among women aged 15 and over-represents a percentage between 71.0 and 77.2 percent. Which means that 3 out of 4 women have a problem with overweight and obesity (Romero, 2013). These records represent a significant change in the epidemiological profile.

In the past, the main problems were infectious diseases and malnutrition. Nowadays, overweight and obesity represent a factor that generates other diseases. Those affect the female population such as cancer (breast, endometrium, vesicle and biliary tract), cholelithiasis and hepatic steatosis (fatty liver), psychological problems (depression and anxiety), peripheral venous insufficiency (varicose veins, edema and trophic changes in the lower extremities) and problems of the locomotor system (osteoarthritis of the spine and knee) (Sánchez-castillo, Pichardo-ontiveros, & López-r, 2004).

Finally, it is important to highlight that in Mexico efforts are being made to reduce the percentage of the female population that suffers from overweight or obesity through health activation programs. The national statistics show that of 56% of the physically active people, only 45.8% corresponds to the female population. Of which, 58% corresponds to women over 25 years. This numbers suggests that the realization of physical activities is essential for this population and are usually a function of the timely disposition of those who perform them. Due to the schedule preference, 41.9% of the population that performs physical activities, prefers a

morning schedule, which is opposed to the period of activities conducted by this population.

Of the physical activities in which the woman has participation, the exercises or routines considered as aerobics, have a preference of 1.6% of the active female population. Which represents the percentage of interest for the present investigation due to the variety of elements of exercise that are used in this discipline as complements to increase the degree of difficulty and the demand of effort on the part of the users.

### 1.2 Axiomatic Design

The methodology and theory of Axiomatic Design (AD) is one of the most cited works in engineering design publications. The state of the AD is the best solution for the design based on two axioms:

1. Maximum independence of functional elements.
2. The minimum information content.

The first axiom ensures that the designs will be adjustable, controllable and avoid unintended consequences. The second axiom guarantees that the design will be robust with a maximum probability of success. The success of the AD consists of three elements each of two parts. The parts of the first element are the axioms, by applying the axioms systematically through the design of the structure where the design of the components is required. The structure is the second element, and its two parts are the horizontal decomposition into client, functional, physical and process domains. And the vertical disintegration into hierarchies from general aspects to specific aspects of the design. The third element is the process. This is a zigzag decomposition to create hierarchies in top-down domains by first performing the functional requirements (FRs) for the client attributes (CAs) in the client domains and then selecting the Design Parameters (DPs) in domains physical to satisfy the FRs and correspond to the Process Variables (PVs) in the process domain to create PDs. The zigzag decomposition continues up and down through the hierarchy of the most specific level of simple design features where the solution is obvious (Suh, 1990, 1995, 2001; Tomiyama et al., 2009).

## 2. METHODOLOGY

A methodology for a systematic search was developed, Figure 1 presents the flow diagram of the method. The following phases integrate this methodology:

- Phase 1. Formulation of the search question from the results of the QFD. In this phase, the core question of the investigation is declared. Because the objective of this project is to present a literature review associated with the design of exercise devices, specifically aerobics. It was established as a restriction that the question should integrate the words: design, ergonomics,

anthropometry, products for exercise, aerobics, product design and axiomatic design.

- Phase 2: Literature Review. During this stage, a database of the Universidad Autónoma de Ciudad Juárez was used as a resource. The database used was: Springer Link, Scopus, Science Direct, Emerald y EBSCOHost. The search syntax as built using the following words: design, ergonomics, anthropometry, exercise products, aerobics, product design and axiomatic design. Search constraint subject to the parentheses functions for different search combined with combinations of them linked to the "and" connector. Search for the concordance in the title of the publication, summary, and keywords. Search restriction by period subject to the interval of years from 2010 to 2018. Spanish and English as a restriction on the language of publication. Consider only scientific articles.

- Phase 3: Reading of information. The process of reading the information lies in the rapid sweep of the information, which consists in first identifying the restrictions considered in Phase 2. With the articles obtained from the discrimination process, the aim is to identify the type of product developed, the author, the design methodology, the tools used, and the design considerations. Typically, we seek to identify the following elements for the first table: Adaptability to human dimensions, design considerations based on posture, use of the client's voice for design, anthropometric considerations, type of grip, weight considerations, considerations of form, Easy to use. For the construction of the second table, we look for information related to the axiomatic design, where the author is identified, the type of product, the axiom used, the complementary methodologies, economic attributes and anthropometric attributes.

- Phase 4: Data extraction. The extraction phase consists of identifying the elements mentioned in stage 3 and proceeding to the identification of the information pertinent to the search.

- Phase 5: Classification of information. The classification phase of the information is developed in two aspects, the first in the allocation of the information obtained to table number 1 called "Product Designs" or to table 2 called "Axiomatic Design."

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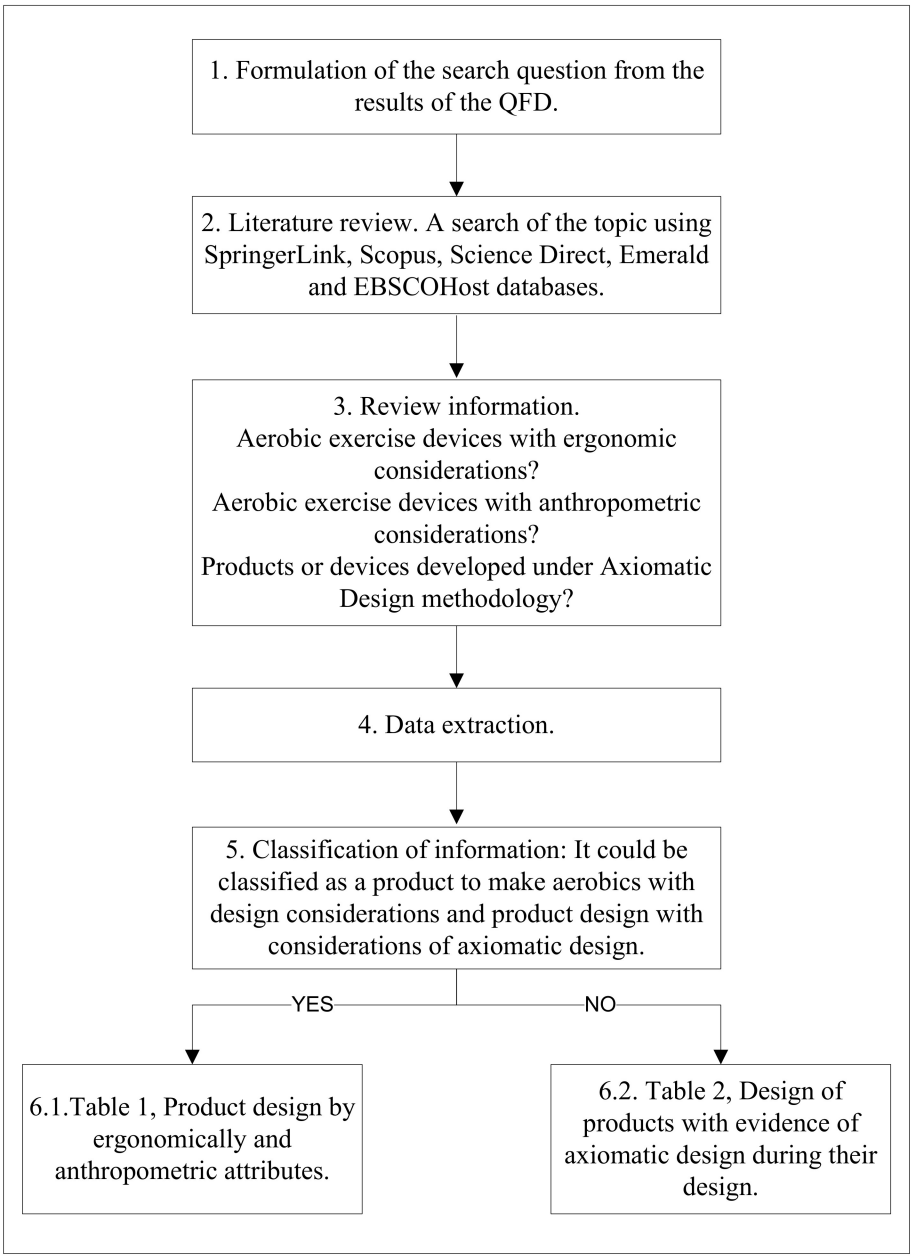


Figure 1. Flow chart of systematic search.

## 3. RESULTS

The results generated by the systematic search, it was possible to build two tables. Table 1, exposes the information made under the restriction of product design of exercise devices ad, table 2 presents the insertion of axiomatic design as a pure or hybrid methodology for product design. Both tables synthetize the information with the aim to show only the most relevant information.

Table 1. Product design by ergonomically and anthropometric attributes.

| Author | Journal | Methodology | Ergonomically attributes | Anthropometric attributes |
|---|---|---|---|---|
| Castellucci, Arezes, & Viviani, (2010) | Applied Ergonomics | Anthropometric measures for design | Students of 8th grade | 6 anthropometric measures: Stature, Popliteal height, Buttock-popliteal length, Elbow height while sitting, Hip width, Thigh thickness and Subscapular height |
| Castellucci et al., (2010) | International Journal of Industrial Ergonomics | Design of ergonomic-oriented | Students of 1st grade in the elementary school | Anthropometric measures such as stature, weight, body mass index (BMI), popliteal height, buttock-popliteal length, and hip breadth shows that stature and body mass index |
| Castellucci et al., (2010) | Applied Ergonomics | Anthropometric measures for design | High school students | Anthropometric measurements (stature, sitting height, sitting shoulder height, popliteal height, hip breadth, elbow seat height, buttock popliteal length, buttock knee length and thigh |

| | | | | |
|---|---|---|---|---|
| | | | | clearance) and five dimensions from the existing classroom furniture. |
| (Castellucci et al., 2010) | International Journal of Industrial Ergonomics | Anthropometric measures for design by mismatch computed through a set of equations | Students of basic and secondary school | Stature, sitting shoulder height, elbow seat height, Thigh thickness, Buttock-popliteal length, subscapular height, and Hip width. |
| Castellucci et al., (2014) | Applied Ergonomics | Anthropometric measures for design by mismatch computed through a set of equations | Students of basic and secondary school | Stature, sitting shoulder height, elbow seat height, Thigh thickness, Buttock-popliteal length, subscapular height, and Hip width. |
| Butlewski, Misztal, & Belu, (2016) | ModTech | Design by modeling | Cognitive techniques, ergonomic modeling | Anthropometric measures. |
| Münster, Schäffer, Kopp, Kopp, & Friedrich, (2016) | Transportation research procedia | Lightweight design automotive | Geometric design phase begins with the positioning of the occupants in the passenger compartment and the ergonomic layout | Anthropometric measures for passenger. |
| Xin, (2017) | Physical Education | Fitness Equipment design | Function, weight, posture. | Anthropometric measures for users. |
| W. Lee et al., (2018) | Computers & Industrial Engineering | Sizing analysis system | Complex body dimensions. | Anthropometric dimensions based on the |

| | | | | |
|---|---|---|---|---|
| | | | | CAESAR head measures. |
| Da Silva, Gordon, & Halpern, (2018) | International Journal of Industrial Ergonomics | Design by anthropometric data base | Workplace, systems, persona protective devices. | Anthropometric measure by six dimensions. |
| Zitkus, Langdon, & Clarkson, (2018) | Applied Ergonomics | Design evaluation tools | Ergonomic task demands | Anthropometric data. |

Table 2 exposes the synthesis of information gained under the search synthases. Due the size of the table, the columns that use number that describes the next information: column with number 1, presence of axiomatic design, column with number 2, presence of information axiom, column with number 3, application area of product design, column with number 4, axiomatic design application, column with number 5, method integrated by more than two design mythologies and, column with number 6, theoretical development.

Table 2. Design of products with evidence of axiomatic design during their design.

| Author | 1 | 2 | 3 | 4 | 5 | 6 | Product | Attributes |
|---|---|---|---|---|---|---|---|---|
| Yang, Yu, & Sekhari, (2011) | X | | X | X | X | X | Refrigerator | +Electronic and electric product.<br>+Product integrated by many components<br>+Recycled. |
| Cheng, Zhang, Liu, Gu, & Cai, (2011) | X | | X | X | X | X | Motherboard of personal computer in a quadrate integrated circuit | + Keep CPU and equipment in a collaborative environment work. . |
| Kremer et al., (2012) | X | | | X | X | X | Ballast arrangement locomotive | + Lack of standardization<br>+ Cost<br>+ Complicated process |
| Lee & Park, (2014) | X | | | X | X | X | Ceiling type air conditioning system | + Air flow<br>+ Capacity of air cool<br>+ Capacity of exchange from heat to cool |
| Song & Zhang, (2013) | X | | X | X | | | Microchanel | + Size of microspheres.<br>+ Consistency of the microspheres<br>+ Flow |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hong & Park, (2014) | X | | X | X | X | X | Water faucet Stering column, ceiling type air conditioner | P1<br>+ Control of water flow<br>+ Control of water temperature.<br><br>P2<br>+ Movement restrictions during assemble.<br>+ Movement control to high and low position of a assemble tube.<br>+ Tube assemble adjust.<br><br>P3<br>+ Minimize the space used by the air conditioned.<br>+ Generate the adequate quantity of air in the area,<br>+ Generate enough cold air,<br>+ Minimize vibration and noise.<br>+ Purify the air in the area.<br>+ Keep temperature programed on equipment and,<br>+ Assure the accessibility to the equipment for maintenance and system fix. |
| Kumar & Tandon, (2016) | X | | X | X | X | X | Hair dryer | + Capacity to dryer.<br>+ Portability.<br>+ Ability to concentrate cold air.<br>+ Security during operation.<br>+ Life length.<br>+ Economy. |

## 4. CONCLUSIONS

The results express the impact in ergonomics and anthropometrics as a principal actor in general process design. Those considerations are logical due to the products nature that is developed for human use or to perform in a controlled environment for people. The results presented in Table 1 refer to the development environment that implies considerations ergonomically in a work area, factors that generate fatigue, environment, among others. Other concern is restricted by anthropometric attributes, which are a restriction for the design of elements that need to be adjusted to a specific population. Is essential mention that the variability is a predominant factor in many people, which tries to be explained and measured by anthropometric studies

that must continuously be updated. Due to the characteristics of the template, only the most meaningful articles are exposed, those cover the conditions of ergonomic and anthropometric attributes. Table 2 present a group of information more critical due to the shortage of existing data in the use of the axiomatic design as a pure or hybrid methodology for the design of products in general. In this way the results obtained in search of these syntaxes is restricted by "product to do exercise," reduces the number of articles published. This represents an area of opportunity for futures searches in the field of exercise products design.

## 5. REFERENCES


Butlewski, M., Misztal, A., & Belu, N. (2016). An analysis of the benefits of ethnography design methods for product modelling. *IOP Conference Series: Materials Science and Engineering*, *145*(4). http://doi.org/10.1088/1757-899X/145/4/042023

Castellucci, H. I., Arezes, P. M., & Viviani, C. A. (2010). Mismatch between classroom furniture and anthropometric measures in Chilean schools. *Applied Ergonomics*, *41*(4), 563–568. http://doi.org/10.1016/j.apergo.2009.12.001

Cheng, Q., Zhang, G., Liu, Z., Gu, P., & Cai, L. (2011). A structure-based approach to evaluation product adaptability in adaptable design. *Journal of Mechanical Science and Technology*, *25*(5), 1081–1094. http://doi.org/10.1007/s12206-011-0224-3

da Silva, G. V., Gordon, C. C., & Halpern, M. (2018). Comparison of anthropometry of Brazilian and US Military population for flight deck design. *International Journal of Industrial Ergonomics*, *64*, 170–177. http://doi.org/10.1016/j.ergon.2018.01.016

FAO, IFAD, UNICEF, WFP, & WHO. (2017). *The state of food security and nutrition in the world 2017. building resislience for peace and food security*. *Fao*. Recuperado a partir de http://www.fao.org/3/a-I7695e.pdf

Hong, E.-P., & Park, G.-J. (2014). Modular design method based on simultaneous consideration of physical and functional relationships in the conceptual design stage. *Journal of Mechanical Science and Technology*, *28*(1), 223–235. http://doi.org/10.1007/s12206-013-0956-3

Kremer, G. O., Chiu, M. C., Lin, C. Y., Gupta, S., Claudio, D., & Thevenot, H. (2012). Application of axiomatic design, TRIZ, and mixed integer programming to develop innovative designs: A locomotive ballast arrangement case study. *International Journal of Advanced Manufacturing Technology*, *61*(5–8), 827–842. http://doi.org/10.1007/s00170-011-3752-1

Kumar, P., & Tandon, P. (2016). A paradigm for customer-driven product design approach using extended axiomatic design. *Journal of Intelligent Manufacturing*, 1–15. http://doi.org/10.1007/s10845-016-1266-2

Lee, S.-J., & Park, G.-J. (2014). A novel method of reverse engineering using axiomatic design. *Journal of Mechanical Science and Technology*, *28*(2), 595–604. http://doi.org/10.1007/s12206-013-1124-5

Lee, W., Lee, B., Yang, X., Jung, H., Bok, I., Kim, C., … You, H. (2018). A 3D

Anthropometric Sizing Analysis System Based on North American CAESAR 3D Scan Data for Design of Head Wearable Products. *Computers & Industrial Engineering*, *117*(May 2017), 121–130. http://doi.org/10.1016/j.cie.2018.01.023

Münster, M., Schäffer, M., Kopp, G., Kopp, G., & Friedrich, H. E. (2016). New Approach for a Comprehensive Method for Urban Vehicle Concepts with Electric Powertrain and their Necessary Vehicle Structures. *Transportation Research Procedia*, *14*, 3686–3695. http://doi.org/10.1016/j.trpro.2016.05.487

Organización Mundial de la Salud. (2017). 10 datos sobre obesidad. Recuperado a partir de http://www.who.int/features/factfiles/obesity/es/

Organización Mundial de la Salud, & Organización Panamericana de la Salud. (2016). Indicadores Básicos 2016. Situación de Salud en las Américas, 9.

Romero, O. (2013). Estadísticas de sobrepeso y obesidad en las mujeres. Características, magnitud y tendencias, 68. Recuperado a partir de http://archivos.diputados.gob.mx/Centros_Estudio/ceameg/ET_2013/07_ESOMC.pdf

Sánchez-castillo, C. P., Pichardo-ontiveros, E., & López-r, P. (2004). Epidemiología de la obesidad. *Mediagraphic*, *140*(2), 3–20.

Song, K. Y., & Zhang, W. J. (2013). Design of a microchannel system using axiomatic design theory for size-controllable and monodispersed microspheres by enhanced perturbation. *International Journal of Advanced Manufacturing Technology*, *64*(5–8), 769–779. http://doi.org/10.1007/s00170-012-4059-6

Suh, N. P. (1990). *The principles of design*. New York: Oxxford University Press.

Suh, N. P. (1995). Designing-in of quality through axiomatic design. *IEEE*, *44*(2), 256–264.

Suh, N. P. (2001). *Axiomatic Design: Advances and Applications*. Nueva York: Oxford University Press.

Tomiyama, T., Gu, P., Jin, Y., Lutters, D., Kind, C., & Kimura, F. (2009). Design methodologies: Industrial and educational applications. *CIRP Annals - Manufacturing Technology*, *58*(2), 543–565. http://doi.org/10.1016/j.cirp.2009.09.003

Xin, F. (2017). Theoretical Analysis and Research Optimization of Fitness Equipment based on Ergonomics, *55*(19), 34–39.

Yang, Q., Yu, S., & Sekhari, A. (2011). A modular eco-design method for life cycle engineering based on redesign risk control. *International Journal of Advanced Manufacturing Technology*, *56*(9–12), 1215–1233. http://doi.org/10.1007/s00170-011-3246-1

Zitkus, E., Langdon, P., & Clarkson, P. J. (2018). Gradually including potential users: A tool to counter design exclusions. *Applied Ergonomics*, *66*, 105–120. http://doi.org/10.1016/j.apergo.2017.07.015