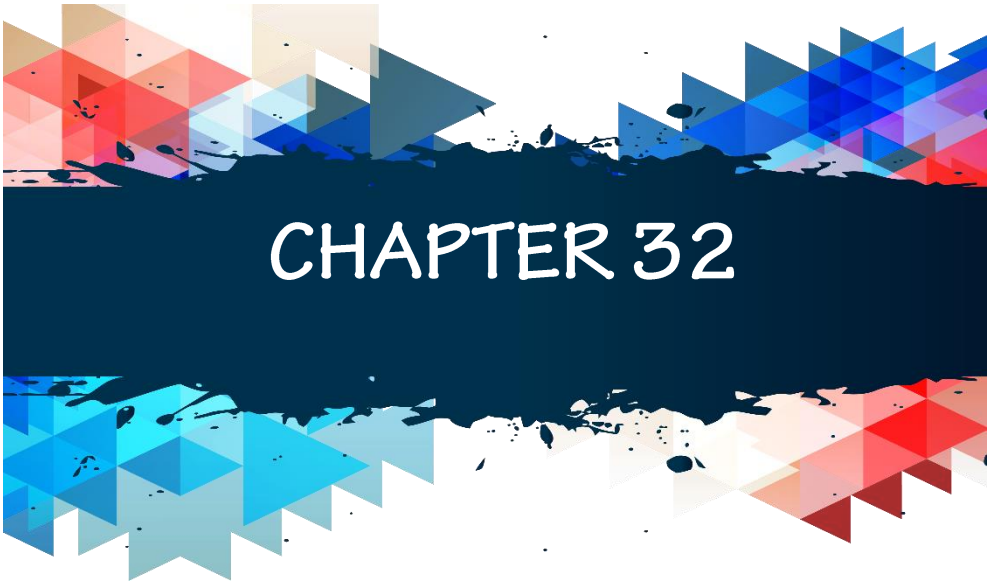

Biomechanical Workload Analysis of Aircraft Technicians

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Introduction

The aviation industry started with Hazerfen Ahmet Çelebi in 1632, continued with the Wright brothers at the beginning of the 20th century, and has come to the present day as a result of a long process and efforts (Kanbur and Gökalp, 2014). With the developments in the aviation sector from the past to the present, the need for aircraft has increased due to the fact that the aircraft have become more technological, large, and complex in this field, as well as the desire of states to be in a strong position in line with their political and military interests, which means an increase in the need for aircraft workers. Increased competition in the marketplace has increased the value of human capital, especially in order to improve quality and achieve greater customer satisfaction.

The increase in the number of people working in the aviation sector, together with the increasing competition around the world, has increased the points to be considered and emphasized in this field. An intensive working process, heavy and fast-paced shifts, the necessity to work in a narrow space, and the necessary maintenance equipment and environmental impacts during the work process can be given as examples. In addition, the working individual also has responsibilities in this process. It is necessary to position the body correctly, select appropriate hand tools, and take individual precautions against hazards that may come from the environment in the workplace. In this regard, especially in aircraft workers, aircraft maintenance technicians face injuries and injuries as a result of the workloads encountered in the aircraft maintenance process.Since injuries can occur, the correct working positions, appropriate equipment, and safety measures for people working in this field are important for the continuity of a healthy process.

1. Aircraft Employees

When aircraft employees are classified according to criteria that require technical knowledge and experience, they are divided into general classes as pilot, mechanical maintenance technician, and avionics technician. Aircraft require maintenance and replacement of necessary parts to ensure safe flight. Aircraft mechanical and avionics maintenance technicians carry out planned maintenance, repair, and inspections in accordance with the required standards and rules in order to keep the aircraft airworthy. From a physical point of view, aircraft maintenance technicians also face physical challenges in this process; pilots, on the other hand, are not exposed to physical work challenges compared to those working in avionics and mechanical maintenance. Pilots are more likely to suffer from neck, back, and lower back pain due to incorrect posture. Aircraft

maintenance technicians, on the other hand, are exposed to heavy physical work, heavy lifting and lowering, pushing-pulling movements, frequent bending and turning, repetitive periodic movements, incorrect movements during work, load on the muscles during the work process, speed and duration of the work, the force and magnitude used during the movement, standing with arms above the shoulders during work, etc. (Yeşil, 2013). The musculoskeletal structure of the body gives rise to the disorders that pilots and aircraft maintenance technicians encounter.

2. Musculoskeletal Disorders

Through the musculoskeletal system, humans fulfill the necessary vital and actional functions with the nerve and brain commands that physically direct the body. Muscles and the skeletal system play a major role in fulfilling the tasks required in the working process. Muscles are the part that uses the chemical energy obtained by the body as mechanical energy. There are types of striated, smooth, and cardiac muscles. Striated muscles are the structures that can provide movement with voluntary control that surround the bone structure in the body. Smooth muscles are involuntary structures found in the internal organs of the body. Although the heart muscle is similar in structure to the striated muscles, it works involuntarily, and unlike other muscles, it fulfills its function not with signals from the brain but with the signals it generates. It only receives its operating frequency from the brain (Serbest and Eldoğan, 2014). Muscles surround the joints and provide a smooth appearance and defense against impacts. The muscles surrounding the joints are connected to the bones with tendons as shown in Figure 1.

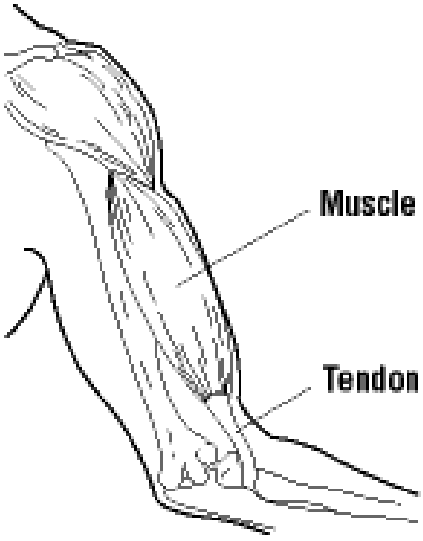

Figure 6.Combination of muscles and bones(URL-1)

The musculoskeletal and skeletal workings of the living body operate on the principle of mechanics as found in physics.Mechanics is one of the five classical fields of physics and studies motion, work, and energy (Karakoç, 2020). Biomechanics also involves the analysis of the principle of mechanics in physics on living organisms. Having different aspects of biomechanics helps to understand different areas of mechanics. For example, while static principles can be used to study force effects in the musculoskeletal system, dynamic principles are used in gait and movement analysis, especially in sports mechanics (Karakoç, 2020). During work, a mechanical action occurs in the striated muscle tissue and skeletal structure as a result of the individual performing actions that require labor. Here the correct body position should be ensured. As shown in Figure 2, an incorrect body position and behavior will cause excessive load on the skeletal structure and cause musculoskeletal disorders.

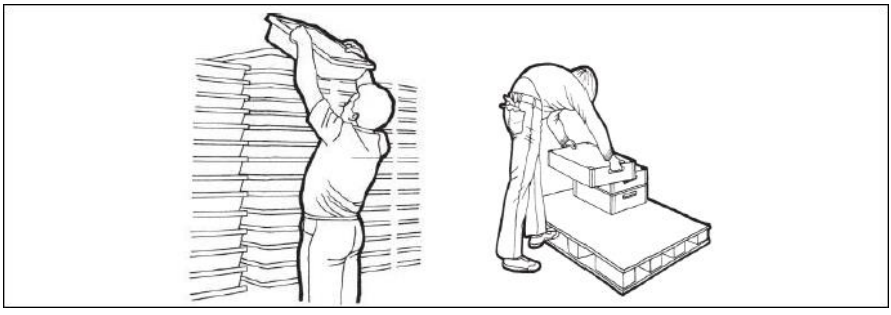

Figure 7.Wrong posture positions(Stephen,2003)

Musculoskeletal disorders are referred to as work-related musculoskeletal disorders in the International Commission on Occupational Health and Safety. The term work-related is used by WHO (World Health Organization) to investigate disorders that may occur due to work performance and the working environment. Musculoskeletal and tendon disorders in working life are caused by holding, compressing, bending, applying torque, reaching somewhere, and repeating this. The negative effects of these actions, which are normally harmless, are caused by repetition and repetition in less time than the time required for the body. At this point, possible risk factors emerge. Although they do not pose a serious risk on their own, the combination of risks at the same time increases the extent of the discomfort. Risks can be listed as body posture, repetition of movement, continuous work, applied force, working speed, ambient temperature, vibration, and working standards.

Fixed shoulders and necks cause discomfort in that area. Because in order to achieve the desired balance in that area, it is necessary to work continuously, and this causes the vessels in that area to be compressed and causes discomfort. In repetitive movements, discomfort occurs due to constant repetition and force application, especially in the moving points of the body, such as the shoulder, wrist, and elbow joints. Working continuously without a break, no matter how light the work is, keeping the muscles constantly working and not taking enough breaks causes injuries. For example, in short-term work (less than 1 hour) in lifting action, a rest period of 1.2 times the working time is given as a rest period. As can be seen in Table 1, studies have been carried out on the periods to be rested for light, medium, and heavy analysis of the work done.

Table 2: Rest time depending on the working interval (sec)(Reinhold,1986)

Operation Time (sec)	Light Operation	Medium Operation	Hard Operation
1	0	1	1
2	1	2	3
3	1	2	4
4	1	3	5
5	1	3	9
6	1	4	14
7	1	5	18
8	1	8	27
9	1	11	35
10	2	14	49
11	2	17	57
12	3	20	62
13	3	24	74
14	3	28	97
15	3	32	111
16	3	36	135
17	3	43	149
18	4	48	158
19	4	53	167
20	5	57	186
21	5	62	220
22	5	67	
23	5	73	
24	5	79	
25	5	86	
30	11		
35	13		
40	15		
45	17		
50	20		
55	25		
60	40		

For long-term work, a morning break, lunch, and afternoon break are also indicated. Lifting, carrying, and applying excessive force will cause too much effort. In this process, overloading the body and continuing uninterruptedly causes the discomfort to occur more quickly. The speed of work will invite musculoskeletal disorders when the individual wants to go above his/her body capacity in order to finish the work on time and wants to do it without a break. Apart from employee-related risks, ambient temperature and humidity are also risk factors in the emergence of disorders. High temperature and humidity tire the worker more, while low humidity causes discomfort during work due to decreased flexibility of the muscles. The minimum temperature values required for working are given below (Table 2).

Table 3: Operating Temperatures(Can, 2013)

Type of Work Performed	Temperature °C
Seated work	19
Standing work	17
Heavy physical labor	12
Offices	20
Indoor sales outlets	19

The use of vibrating tools and instruments will also cause damage to the hand and nerves, leading to numbness of the fingertips and senses. For example, using a heavy hand tool, such as a hammer, will cause vibration, leading to the common Raynaud's Syndrome. As a result of the aforementioned risk factors, the main musculoskeletal disorders resulting from work are back pain, muscle strain, stiff neck, cervical disc herniation, lumbar disc herniation, carpal tunnel syndrome, stiff neck syndrome, and muscle strength imbalances(Esen and Fığlalı, 2013).The most obvious sign of musculoskeletal disorders is pain. In some cases, symptoms such as swelling, edema, redness, stiffness, and numbness also occur in the relevant area.

Bursitis: It occurs in the soft tissues between bone-tendon or skin-bone. Swelling and pain symptoms occur in the relevant area. Repeated shoulder movements and mechanical pressure on the elbow cause this condition.

Carpal Tunnel Syndrome: It is caused by compression of the nerves passing through the wrist. It shows symptoms in the form of tingling and numbness in the fingers at night. Working with a bent wrist and using vibrating hand tools cause this condition.

Cellulitis: It occurs as a result of repeated injuries to the palm. Pain and swelling in the palm are the most common symptoms. Using impact-causing tools such as hammers, etc., can cause this condition.

Epicondylitis: It occurs as inflammation occurring at the bone-tendon junction. It shows symptoms as pain and swelling in the relevant place. Repetitive movements in jobs requiring force cause this discomfort.

Ganglion: It occurs as a result of cyst structures that occur in the sheath of joints or tendons. It shows a painless symptom in a small area. Discomfort occurs as a result of repetitive hand movements.

Osteoarthritis: Inflammation of the joint and bone surfaces. It shows symptoms in the form of stiffness and pain in the spine, neck, and other joint areas. Prolonged loading of the spine and related joints causes this condition.

Tendonitis: It occurs as tendon inflammation. It is manifested by symptoms such as redness, pain, swelling, and tenderness in the upper arm, wrist, or hand, as well as an inability to get full efficiency when using the hand. Repetitive working movements cause this discomfort.

Tenosynovitis: It is a discomfort due to inflammation in tendons and their sheaths. It shows symptoms such as pain, swelling, extremely severe pain, and difficulty in using the hand. Sudden increases in workload cause this condition.

Pressure on the Neck and Shoulder: It is a condition that occurs with inflammation in the neck and shoulder muscles and tendons. It manifests as local pain in the neck and shoulder area. Constantly working in the same position causes this discomfort.

Trigger Finger: Inflammation of the tendons and sheaths of the fingers. It shows symptoms such as inability to move the fingers comfortably, locking when the finger is curled, and pain when moving it. Squeezing and grasping a tool for a long time with repetitive movements causes this discomfort.

White Finger Vibration: It is stated as neural changes and vascular contractions in the finger and forearm. It usually shows symptoms as numbness and tingling in cold weather. Using vibrating hand tools causes this discomfort.

Back and Waist Disorders: They are tensions and strains that occur in the structure of the spine. It usually shows symptoms with pain in the strained part and forcing movement. Behaviors such as lifting more than necessary, standing in an incorrect body position, and straining cause this discomfort.

Lumbar Hernia: It occurs when the anatomical integrity of the layer outside the elastic cartilage structure between the vertebrae in the lumbar region is disrupted due to the compression of the vertebrae, and the soft part inside protrudes outward (Çevikcan and Kara, 2007). Behaviors such as working in the wrong position, lifting heavy loads, and working from a seated position cause this discomfort.

For this reason, the movement management of the musculoskeletal system should be provided with the correct position and force to avoid permanent damage to the body or damage that affects the quality of life. Another situation to be considered is that the equipment used during work should be suitable for the working individual. At this point, we come across anthropometry. The fact that the equipment is suitable for the working individual will also increase the efficiency at work. Because the physical comfort of working people and their ability to use their physical abilities at the maximum level depend on the suitability of the materials, work surfaces, and volumes they use with their own dimensions (Bulut and Kıran, 2015).

3. Anthropometry

Anthropometry is a term that comes from the Greek words anthropos and metrikos. It can be called human measurement. Anthropometry measures the body according to some standards and analyzes it statistically (Figure 3). It is based on determining the measurement of all kinds of independent equipment, hand tools, and clothes, especially in business areas, and designing them in accordance with human beings.

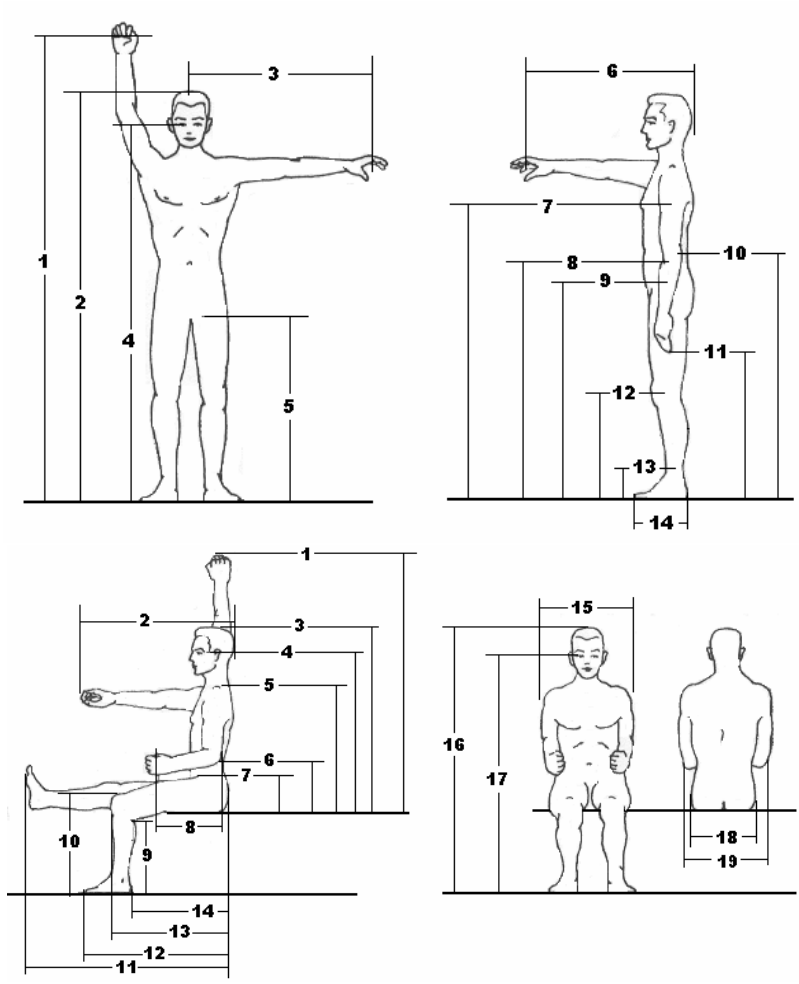

Figure 8: Dimensions used in static anthropometry studies(Kaya,2008)

Today, with the rapidly developing technology, business life is also undergoing changes. Employees who take an active role in the front field are physically and psychologically burdened due to the intense and heavy work pace. One of the reasons for this is that the equipment and hardware used are not suitable for the working individual. As a result, the working individual will have to bend, reach, or apply more force than they should, and problems due to strain will appear. It should not be forgotten that the musculoskeletal system of the working person has a certain limit strength. Therefore, compatibility between human and work should be ensured. Expecting people to do more than the work

they can do will have negative consequences and will reduce the quality of the employee and the work.

It is accepted that approximately 80% of occupational accidents are related to people, 18% to physical and mechanical environmental conditions, and 2% to unexpected events (Camkurt,2007). This shows that unwanted mishaps can be avoided to a great extent. What needs to be done here is to achieve compatibility between work and people. However, the key point here is to make the work suitable for people, not people for work. During the inspection, there are many different criteria ranging from the work area, the equipment used, to the physical condition of the environment. The use of appropriate equipment and tools during work is one of these criteria. Therefore, it can be said that the goal of anthropometry is to ensure that the right equipment is suitable for the individual during the work and that the working individual can devote himself to his work with full efficiency and health.

3.1. Anthropometric Design Approach To Equipment

Equipment is expected to perform the task for which it is designed well, to meet the needs of the maximum possible number of users, and to be inexpensive. This means that a piece of equipment is designed for potentially all users. It is also expected to provide good comfort and reduce biomechanical demands. The use of hand tools, in particular, covers a wide range of industries, and it is mostly the upper musculoskeletal region where accidents and injuries occur (Aptel at al.,2002). A study has shown that 24% of musculoskeletal accidents are related to hand tools (Myers and Trent, 1988) When designing a hand tool, it should not be overlooked that the user, the tool, and the working environment are an inseparable whole. Each of them is in a relationship with the other two, and the design of the hand tool is realized with an ergonomic approach. In general, three basic processes emerge in the design of hand tools (Aptel at al.,2002):

- Determining the needs and requirements of the employee according to anthropometric measurement criteria after observing the work process and work context
- After the initial process, testing of new prototypes according to tool specifications and laboratory simulations and examination of their biomechanical demands
- After the second stage, the new prototypes are tested in the real business sector over a long period of time.When satisfactory results are obtained, the prototype is accepted and approved.

The important point here is that users carefully test these new tools for a long time before making a final decision.

4. Biomechanics

Biomechanics studies the physical structure of the musculoskeletal and biological movement systems. Therefore, biomechanics can be considered as a part of mechanics. Because the working principle of some parts of the human body is similar to the working principle of a machine (Çalışkan and Fındık, 2012). Today, biomechanics covers the force-motion relationship of organs, load lifting, the operation and modeling of joints, diagnosis, and treatment studies in the field of sports and health. Research on biomechanics is basically divided into three separate sections: experimental research, applied research, and model analysis research. Experimental research includes studies on organs such as muscles and bones. Applied and model analysis research includes studies that are carried out by modeling existing research and studies without the need for experiments. Applied research includes useful research obtained by putting existing knowledge into practice. Biomechanical research can be in the field of occupational health and sports. Biomechanical research in the field of sports is carried out to ensure the highest efficiency and success of the athlete. Biomechanical research in the field of health includes injuries, musculoskeletal movements, and treatments of the human body. Occupational biomechanical research is carried out to reduce occupational accidents and physical difficulties while working in a healthier and more comfortable work environment (Karakoç,2020).

4.1 Musculoskeletal Biomechanics

The realization of movement in the human body is the result of the joint work of the muscular, skeletal, and nervous systems. The skeletal system protects the internal organs, acts as a place to attach to the muscles through tendons, shapes the body and provides uprightness, and has an important role in the movement of the body. The bones that make up the building blocks of the skeletal system are resistant to compression and can regenerate themselves after damage. Cartilage tissues, another element of the skeletal system, are three in number. Hyaline cartilage is found at the ends of long bones, elastic cartilage is found in places that do not ossify, such as the ear, and fibrous cartilage is found in the discs between the vertebrae and at the points where tendons and bones meet. In the muscular system, they are the structures that provide movement with the skeletal system. There are striated, smooth, and cardiac muscle types, and the striated cardiac muscle accounts for approximately 40-45% of body weight. Striated

muscles provide a regular distribution of the load on the body and protect the skeleton during movement (Karakoç,2020).

Conclusion

Aircraft maintenance technicians perform actions such as transportation, maintenance, repair, etc., and as a result, the risk of musculoskeletal injuries is quite high. Approximately 35.4% of the cases reported in this field are musculoskeletal disorders, and the neck, back, head, and lower parts are the most affected parts (Asadi, 2019)

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